Environmental River Enhancement Programme

Annual Report 2019

IFI/2020/1-4515

Iascach Intíre Éireann
Inland Fisheries Ireland

EREP 2019 Annual Report

Inland Fisheries Ireland & the Office of Public Works

Environmental River Enhancement Programme

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Inland Fisheries Ireland

OPW Oifig na nOibreacha Poiblí
Office of Public Works

Acknowledgments

The assistance and support of OPW staff, of all grades, from each of the three Drainage Maintenance Regions is gratefully appreciated. The support provided by regional IFI officers, in respect of site inspections and follow up visits and assistance with electrofishing surveys is also acknowledged. Overland access was kindly provided by landowners in a range of channels and across a range of OPW drainage schemes.

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Foreword

Welcome to the Environmental River Enhancement Programme Annual Report 2019. The EREP is a collaborative research programme funded by the Office of Public Works (OPW) and managed by Inland Fisheries Ireland (IFI).

The EREP evolved from previous joint research efforts between the two state agencies to understand the impacts of arterial drainage maintenance on the river corridor, its habitat and biota including fish. Initial research was undertaken in the 1990s as part of the Environmental Drainage Maintenance (EDM) studies, forming the basis for the current OPW guidance and training on environmentally-friendly maintenance measures. Additionally, at this time, river enhancement works developed by IFI and OPW were implemented as part of the Tourism Angling Measures (TAM). Both of these aspects – environmental maintenance and enhancement – are the framework for the EREP which was formalised in 2008, initially for a five year period. The main aim of the programme is to promote positive river enhancement measures which maximise environmental gain, whilst facilitating OPW's statutory drainage remit under the Arterial Drainage Acts (1945, 1995).

Since 2008 the EREP has been developing knowledge and datasets for channelised river catchments, with baseline monitoring at a catchment-wide scale and specific scientific studies conducted at a reach-scale. This report details the second year of activity within the current EREP five year period (2018-2022).

Underpinning all EREP activities is the Water Framework Directive (WFD) with the requirement to improve the ecological quality of watercourses and achieve "good status". In that respect, catchment-wide survey results are compatible with WFD classifications (High, Good, Moderate, Poor or Bad). Particular emphasis has been placed on hydromorphology as a relevant element of the EREP, focussing on lateral and longitudinal connectivity, as well as the morphological conditions of the instream and riparian zones. Research identifying deficiencies in these areas of hydromorphology within drained or channelised river catchments is evidenced throughout the report, and these outcomes can inform management decisions on appropriate measures which could potentially improve hydromorphology.

The IFI EREP team have adapted to the continual developments in technology and use mobile web-mapping applications and drones for data collection in the field. As well as providing data to the OPW which is relevant for their maintenance teams, these survey efforts in generating fish and habitat data have direct synergies and relevance to other work programmes within IFI. In particular, datasets have been provided to the National Barriers Programme, EU Habitats

Directive project and the INTERREG CatchmentCARE project. These positive collaborations amongst teams outside and within IFI represent efficient use of resources within the civil and public sectors across the island of Ireland.

Finally, I would like to thank all those who contributed to this report, to congratulate them on the work completed and to wish them well in the year ahead.

Cathal Gallagher

Dr. Cathal Gallagher, Head of Research & Development

Inland Fisheries Ireland, September 2020

Executive Summary

In 2019, a catchment-wide survey was completed on the Deel catchment, with a majority of survey sites located within the OPW drainage scheme and a minority outside of the scheme in the upper tributaries. A total of 47 sites were fished and of these 26 had a hydromorphological assessment carried out. Ecological Quality Ratios calculated for the Deel fishing sites classified 53% of sites as Moderate status and 34% as being in Poor status. Just 13% of sites passed the WFD minimum requirement of Good status. From a hydromorphology perspective, 19% of sites passed the WFD minimum requirement of Good status, with 50% categorised as Moderate, 27% as Poor and 4% classified as having a Bad status. 464 of the 769 in-stream structures identified as potential barriers were visited and assessed. Of those structures assessed to date, 63 (13.5%) were assessed as barriers to fish migration, including 44 culverts/bridge aprons, 3 sluices, 15 weirs, and 1 natural barrier (waterfall). Six of the weirs are located within the lowest 1.2km of the catchment and represent significant obstacles for a range of migratory fish species.

Physical surveying of the long-term Capital Works site at the Enfield Blackwater shows the measures introduced in 2010 (including paired deflector/pool complexes and gravel shoal/pool complexes) have largely remained intact. The thalweg introduced at this site has migrated within the channel confines showing the capacity of arterially-drained channels to re-establish river function. Depth-velocity data indicates localised changes in channel form and flow as a result of the Capital Works structures. From the fish survey, there is evidence that a variety of age classes are supported at the sites, with pools providing suitable refuge habitat for older fish and the shallows providing suitable juvenile or spawning habitat.

The River Eignagh was re-surveyed in 2019 as a long-term Enhanced Maintenance site. Two rounds of maintenance by OPW, in 2005 and 2014 respectively, had a large and measurable impact on recorded canopy cover. Pre-maintenance levels of riparian cover had not re-established five years later. A consistent brown trout population structure was recorded over the study period, and no relationship was observed between fish and physical variables examined.

Channel modifications of the cross-section and longitudinal section during routine maintenance were examined in the context of three long-term study sites in the River Clonshire (Maigue), River Dungolman (Inny) and Tullamore Silver (Brosna). Under the OPW's 10-point environmental guidance, these channel modification measures are incorporated as steps 7 (berm management) and 10 (excavation within the channel). Common conclusions could be drawn from the surveys at all sites including the importance of the bed material and gradient

as two factors which are critical in the success or longevity of any enhanced maintenance measures. Retention of pool-riffle sequences was evident in the River Clonshire, 12 years after implementation. In the River Dungolman, excessive berm loss was attributable to maintenance. However the river shows potential for recovery of these channel features, and if the agreed strategy of berm-topping is adhered to, potential benefits of a narrower wetted width and establishment of marginal vegetation may be re-gained. Re-profiling the cross-sectional form in the Tullamore Silver has created positive impacts from both channel maintenance and fish perspectives. Alteration of the physical form of the channel facilitated changes in instream and marginal vegetation with reduced levels of flaggers and increased levels of marginal grasses, providing cover for brown trout populations.

Some novel strategies were implemented during OPW channel maintenance in 2019, in the Eignagh River and River Cor. Both measures involved the re-use of timbers removed during maintenance. On the Eignagh, simple low-level instream deflector structures were installed, and on the Cor the timbers were used as soft/green bank protection structures. Other enhanced maintenance measures including berm management and re-profiling the channel bed (both part of the OPW’s 10-point environmental guidance) were also evidenced to good effect on the River Cor.

Barrier assessment surveys using the WFD 111 method developed by SNIFFER have now been completed by IFI staff on all of the OPW gravel/sand traps which present fish passage problems (9 out of 12). Those surveyed in 2019 and early 2020 are briefly presented in this report, with a separate report issued to OPW detailing the fish passage issues present at each of the structures. OPW commissioned JBA Consulting to undertake a review of all of the structures in regard to hydromorphology issues. It is envisaged that a combination of outcomes from the two studies would be informative to OPW in addressing these structures, their current impacts, and the impact of their removal or other mitigation option.

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1 Introduction

A new five year agreement (2018 – 2022) between the Office of Public Works (OPW) and Inland Fisheries Ireland (IFI) saw the EREP programme for 2019 focussing on a series of agreed investigations. These would provide the OPW with information on issues within drained catchments pertinent to the Water Framework Directive (WFD) and implementation of Programmes of Measures (POMS) in regard to WFD. The programme included collection of new data sets as well as returning to sites of previous detailed studies. The latter is designed to build up long-term time sequences of data, highly valuable in looking at changes arising from OPW's work in EREP, which may take considerable time to come to full development. Data collection and analysis of more recent data has focussed on generating Ecological Quality Ratios or EQRs from the fish and habitat data collected. The EQR is a basic 'currency of ecological quality' for WFD and so provides an immediate snapshot for channel managers, including OPW, on the status of rivers and channels. In line with current emphasis in the current Cycle 2 of WFD, and with the scope of OPW's channel works impact on channel form and function, the studies in EREP 2019 had a strong hydromorphological emphasis. This included compilation of Rapid Hydromorphology Assessment Technique or RHAT scores at survey sites as well as repeat habitat surveys at sites of Capital Works and of Enhanced Maintenance where pre- and post- works data on cross-sections and longitudinal profiles were compiled. Compilation of a barrier inventory in selected OPW catchments is on-going as part of EREP. Knowledge of barrier location and an understanding of the impact of barriers on fish passage and on sediment transport allow for these issues to be identified in the course of works scheduling, with the potential for passage issues to be addressed by way of capital works as and when maintenance work overlaps with identified barriers. A barrier inventory programme was commenced in the Deel catchment in 2019. In addition detailed SNIFFER surveys were completed on a series of gravel traps managed by OPW in various drainage schemes. The SNIFFER fish passage surveys complemented a series of overview hydromorphology surveys undertaken for OPW by JBA Consulting. Some novel strategies were implemented in maintenance during 2019, two of which are reported on; involving re-using timbers removed during maintenance to (a) construct simple low-level instream deflector structures and b) their use as soft/green bank protection structures in a second case.

2 Deel catchment-wide survey programme

2.1 WFD background to EQRs and hydromorphology

The WFD was the original driver for the EREP studies, commencing in 2008, with a focus on addressing channels impacted by arterial drainage. The physical effects of drainage schemes negatively impact channel hydromorphology – meaning the hydrology and channel form – such as the instream and riparian condition, as well as channel continuity, both longitudinally and laterally. The physical impacts, in turn, influence and control the biology of the instream fauna (fish and invertebrates) as well as vegetation in the channel and on the bank slopes.

The WFD looks at 'ecological quality' by examining a range of biological indicators or Quality Elements and generating Ecological Quality Ratios (EQRs) for each indicator type (fish, aquatic plants, benthic invertebrates etc.). The scoring (between 0 and 1) for each Quality Elements then classifies the selected waterbody into one of the following categories: High; Good; Moderate; Poor; Bad. This is the underlying aim with the timed electric fishing survey programme (FPI) that IFI has developed and has been undertaking annually as part of the EREP deliverables. The FPI Survey allows a biological quality ratio to be generated for each fishing site i.e. a fish EQR for each site surveyed in OPW catchments.

The WFD also takes physical habitat into account. Rapid Hydromorphology scoring (River Habitat Assessment Technique: RHAT score) provides a quality rating for a suite of hydromorphology elements. By collecting both fish and hydromorphology data using WFD-compliant methods at all study sites, EREP can compare data sets from multiple locations and examine how the fish community may be impacted by the overall hydromorphology.

Longitudinal continuity allows for a natural river flow regime and allows migration of biota up and downstream as well as downstream sediment transport. The presence of discontinuities such as perched bridge floors, drop structures, weirs and dams in channels interferes with natural longitudinal continuity. These impediments can interfere with upstream migration of fish species e.g. elver life-stage of European eel, adult lamprey and Atlantic salmon migrating to spawning locations as well as downstream migrations of adult silver eels and salmon smolts. The aim of the barrier survey is to examine all potential barriers, using a desk- and field assessment method to collect baseline information of structures considered as obstacles to fish passage. The outcomes provide a GIS-based layer of barriers within the whole catchment that could be examined by the resident engineer and foreman of OPW in planning any maintenance programmes for this area. Visual examination of barriers prior to maintenance could signal what works are necessary to offset the adverse effect of the barrier. This would constitute legitimate use of Capital Works funds by OPW. In many cases, the remedial works would address any adverse structural effects such as scouring of the bridge floor, at a particular site. In other words, the project would provide baseline information for WFD compliance as well as informing OPW on the status of some of its infrastructure.

2.2 The Deel catchment survey 2019

The main river Deel and its tributaries were subject to arterial drainage in 1962-68. The catchment covers an area of 547 km^2 and discharges to the lower Shannon estuary (Figure 2.1). It is bordered to the west and south by hills including the Mullaghreirk range but overall is relatively flat, with a maximum elevation of 362m in the headwaters. The underlying bedrock geology dictates this topography with most of the Deel catchment area comprising a complex inlier of Devonian sandstone to Carboniferous age limestones, with the mountainous plateau along the southern and western fringes comprising of younger shales and sandstones. The substrate underlying the majority of the watershed area is glacial tills, with intermittent sand and gravel deposits and a narrow corridor of alluvium. In the lower part of the catchment area there is exposed karst bedrock and peat. Throughout the Deel catchment the majority of the land use is pasture.

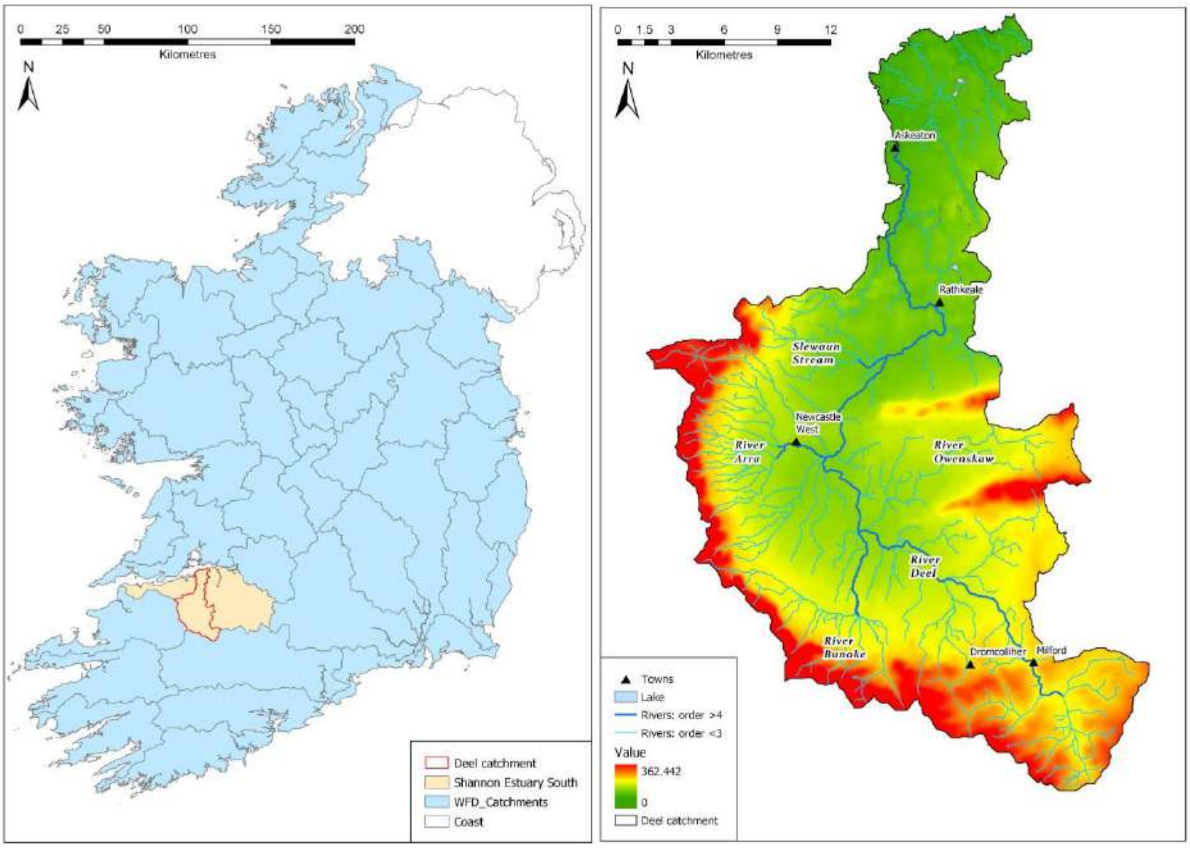

Figure 2.1 Location of the Deel catchment (left) and geography of the Deel catchment (right) showing major tributaries, towns and elevation.

The main River Deel rises near Dromina in north Cork and flows north into County Limerick for over 60km to enter the Shannon Estuary at Askeaton. The river flows through Milford, then on toward Castlemahon and into Newcastle West. It then flows in a north-easterly direction to reach Rathkeale and then on towards the estuary at Askeaton. The major tributaries include the River Bunoke, River Arra, Slewaun Stream and River Owenskaw. All of the higher order channels form part of the OPW drainage scheme, apart from the upper 4th order section of the River Bunoke. The remaining channels, not part of the drainage scheme, are all 3rd order channels or lower order streams (Figure 2.1)

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2.3 Fish Population Index (FPI)

The Deel Basin, Co. Limerick was surveyed during the months of August – September, 2019. In total 47 sites were surveyed (Figure 2.2) in order to determine the density, distribution and population structure of the fish communities along with the hydromorphological pressures which could be affecting them.

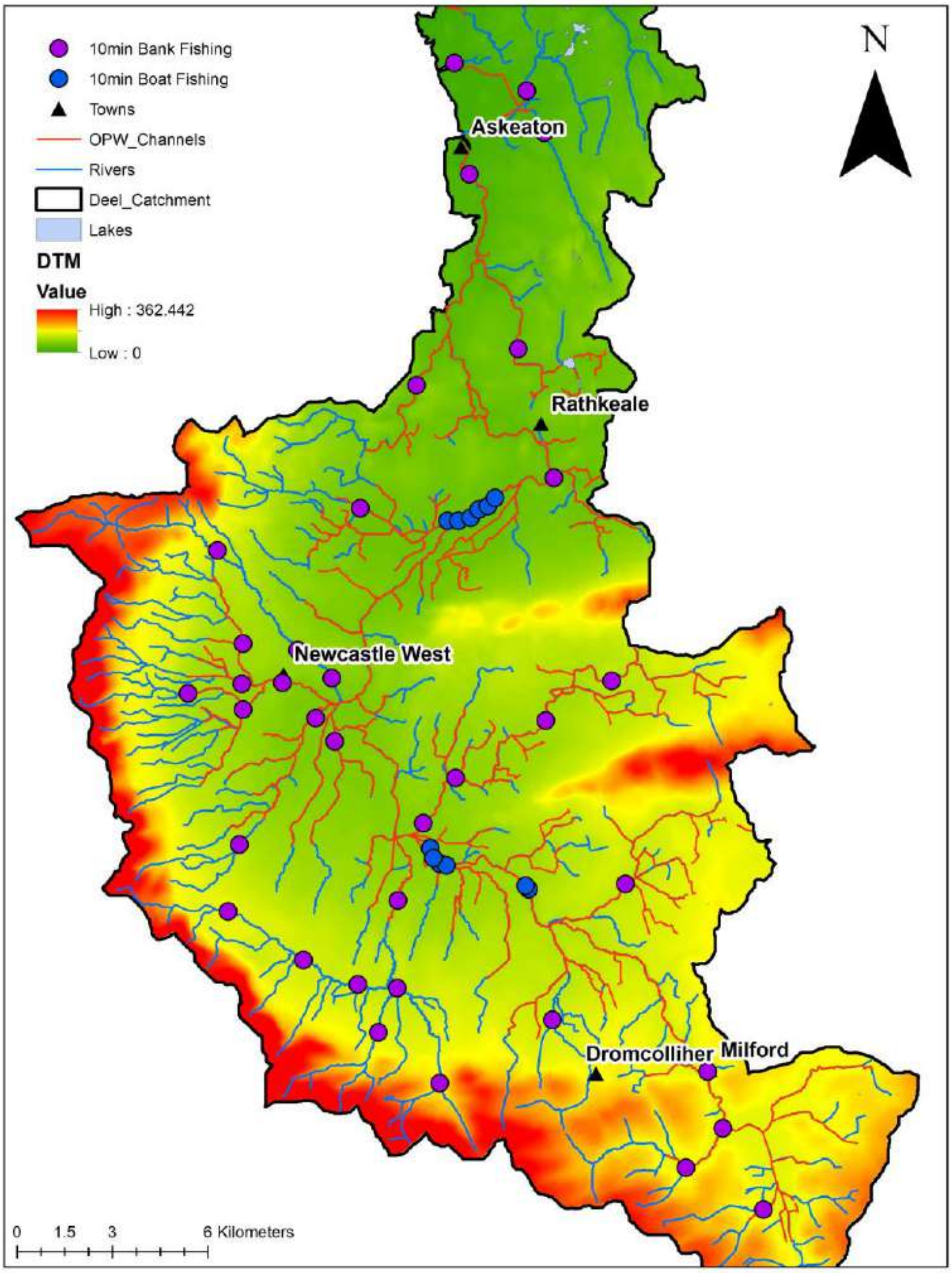
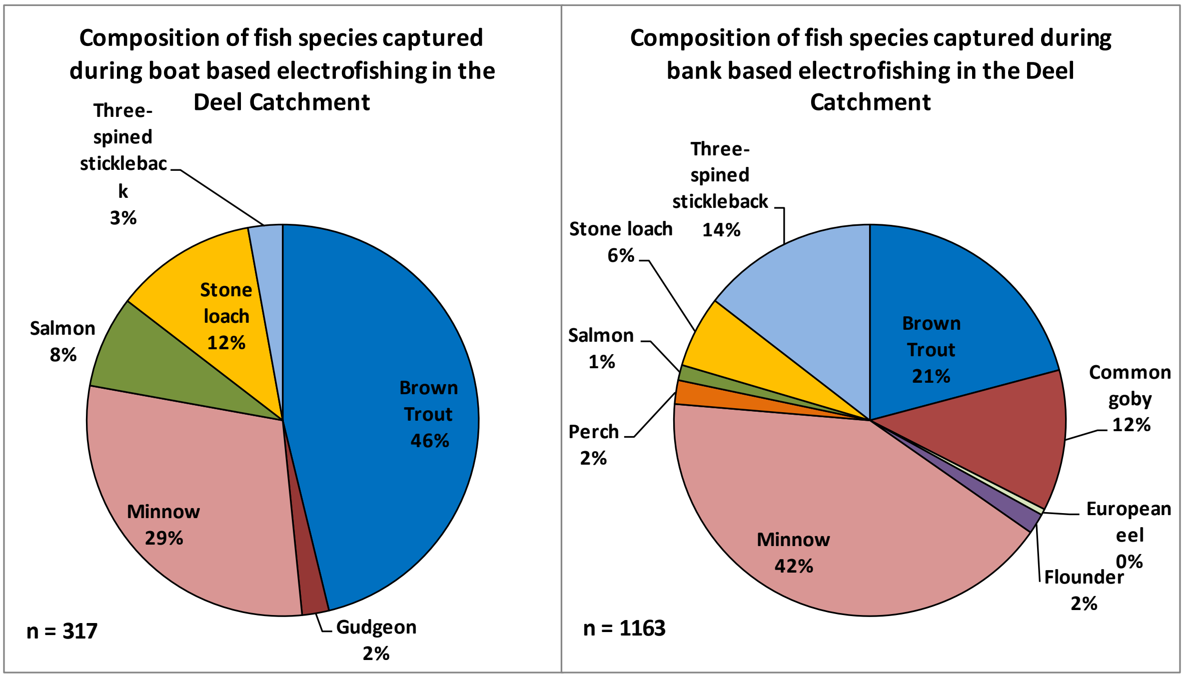


Figure 2.2 Digital terrain map (DTM) of the Deel Basin and locations of electrofishing sites fished during the FPI Survey 2019 (DTM scales is in metres).

In completing the 2019 FPI survey, 36 bank-based and 11 boat-based electrofishing sites were fished. The boat sites were located on the main stem of the river Deel. In total, 1480 fish were captured, measured and returned during the survey. Brown trout was the most abundant species encountered in the boat fishing whereas the bank based fishing catches were dominated by minnow, followed by brown trout and 3-spined stickleback and the common goby (Figure 2.3). Common goby were abundant at one of the bank sites located in north of the catchment close to the estuary, where brackish water provided suitable goby habitat.



Composition of fish species captured during boat based electrofishing in the Deel Catchment

Composition of fish species captured during bank based electrofishing in the Deel Catchment

Figure 2.3 Composition of fish species captured in the Deel FPI survey using bank and boat based electrofishing equipment.

Trout were present at 77% of the sites surveyed. Only a small percentage (6.6%) of the brown trout captured during the survey was of angling importance (26 trout > 28cm in length, Figure 2.4). By comparison salmon were only present at 18% of sites surveyed in 2019 (Figure 2.5).

During the bank based electrofishing a range of age groups of brown trout were captured. Three modal peaks were evident in the trout length frequency data compiled (Figure 2.4). Fish under 10cm were classified as 0+ brown trout i.e. those spawned in the previous winter, and there was a prominent cluster of fish in the 7-9 cm range. The second modal group, in the 16 – 22 cm range, was dominated by 1+ year old fish. Fish in excess of this size consisted of 2+ year old trout and older fish. The bank/handset fishing sites, in water no deeper than 0.5m, were acting as brown trout recruitment and nursery areas. Boat based fishing, aimed at deeper sites, captured brown trout of a larger size range (up to 39cm) (Figure 2.4). Adult trout move to deeper areas after spawning for better feeding opportunities. The survey results show the importance of a range of different channel sizes, at a catchment scale, for the different life stages of brown trout (Figure 2.5).

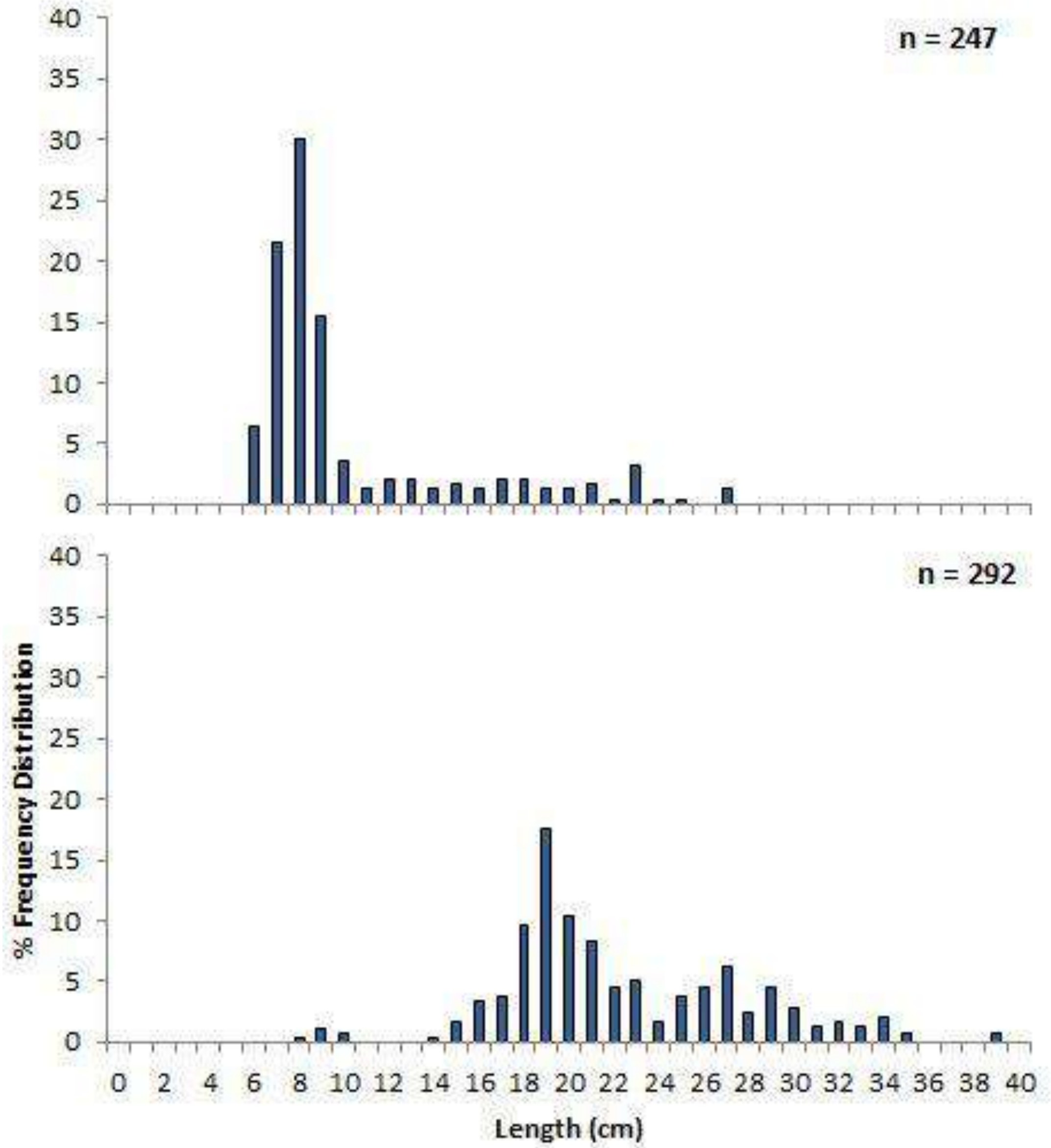


Figure 2.4 Percentage length frequency distribution of Brown Trout captured by bank- (top) and boat- (bottom) based electrofishing from the Deel FPI Survey in 2019.

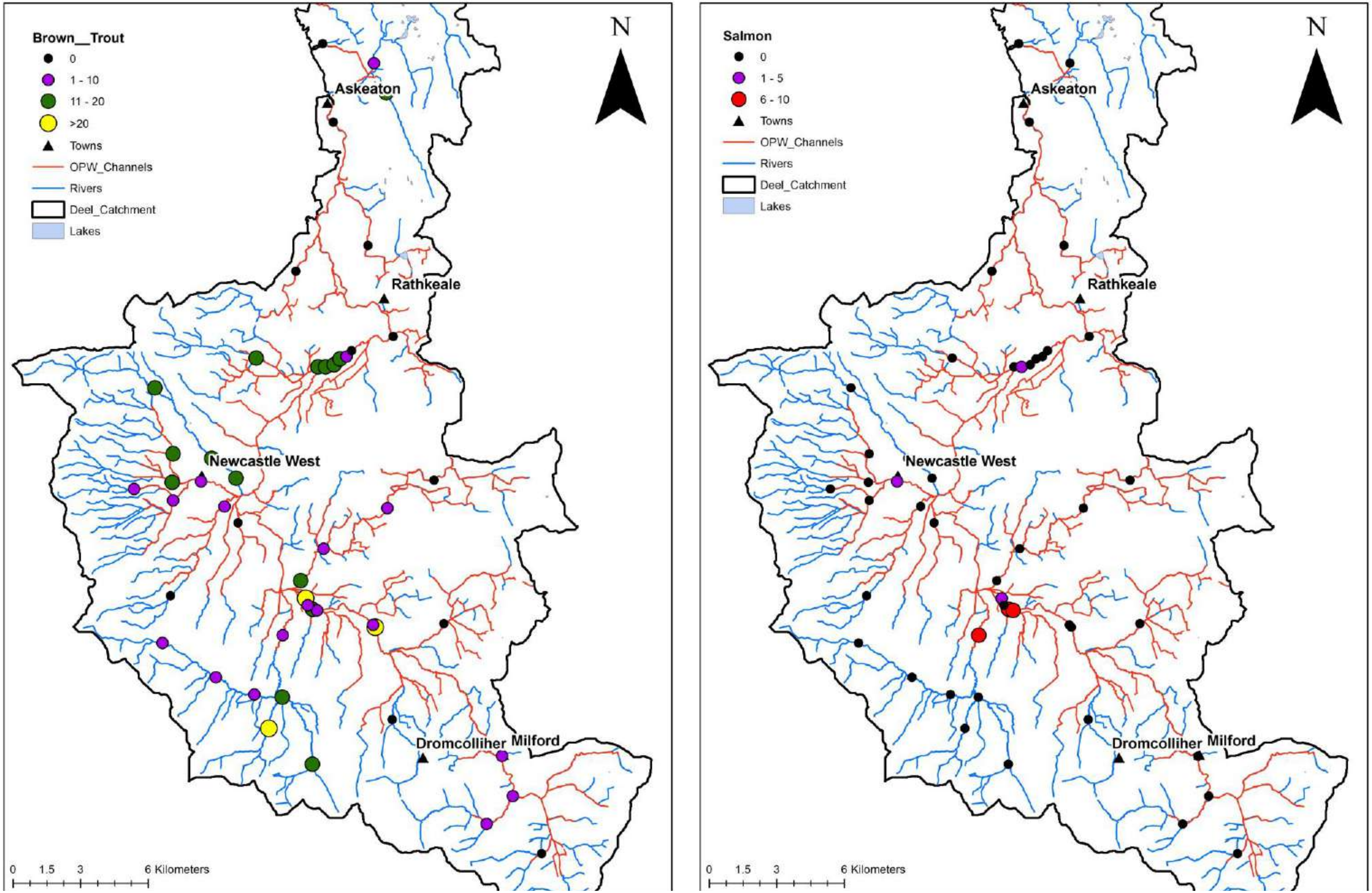


Figure 2.5 Brown Trout and Salmon numbers captured per 10 minute electrofishing session at each site in 2019.

2.3.1 Ecological Quality Ratio (EQR) for the fish community in the Deel

EQR Scores for fish were generated for the 47 sites fished in 2019. In addition, 13 of these sites were previously fished in an EREP study in 2009 and EQR Scores are available for comparison. From the sites fished in 2009, 4 were upgraded from Poor to Moderate Status. One site was downgraded to Poor Status and 3 sites remained as Moderate Status for both years (Figure 2.6). Following the 2019 survey, 53% of sites in the Deel were graded as Moderate status and 34% were classified as Poor Status (Figure 2.7). Many of the fishing sites in the smaller tributary channels, not part of the OPW Deel drainage scheme, registered a Poor Status EQR for the fish attribute (Figure 2.7).

The basic WFD requirement is for Quality Elements, fish in this case, to be of Good Status, therefore only 13% (n=6) of the sites in the Deel catchment are meeting WFD standards.

Presence and absence of salmonids influence the EQR scores given to a water body. When calculating an EQR Score for any waterbody salmonids are scored for presence of both 0+ and 1+ fish i.e. two separate age groups. This plays a significant role in the model output. If both 0+ and 1+ salmon are recorded during the fishing survey the waterbody will achieve a higher EQR score, whereas if only one age class was present the riverine system would achieve a lower EQR score. Both classes of salmon and trout recorded during an electrofishing survey indicate species recruitment. Focusing solely on salmon records, 37% of sites classified as Good Status had both age classes of salmon present and 38% had one age class present. Sites classified as Moderate Status had salmon present in two (7%) sites. Salmon was absent from 96% of those sites scored as Poor. Brown trout influences EQR scores in the same way as salmon presence. The EQR scoring system accounts for the diversity of species present in a waterbody - including lamprey, crayfish, stoneloach, stickleback, minnow and others along with 0+ and 1+ salmonids. If salmon were more widespread and more abundant in the Deel this would influence and improve EQR results. The six weirs at Askeaton (section 2.5.1, pg. 25) present a significant barrier to migration of salmon, particularly for incoming adult salmon migrating into freshwater to spawn.

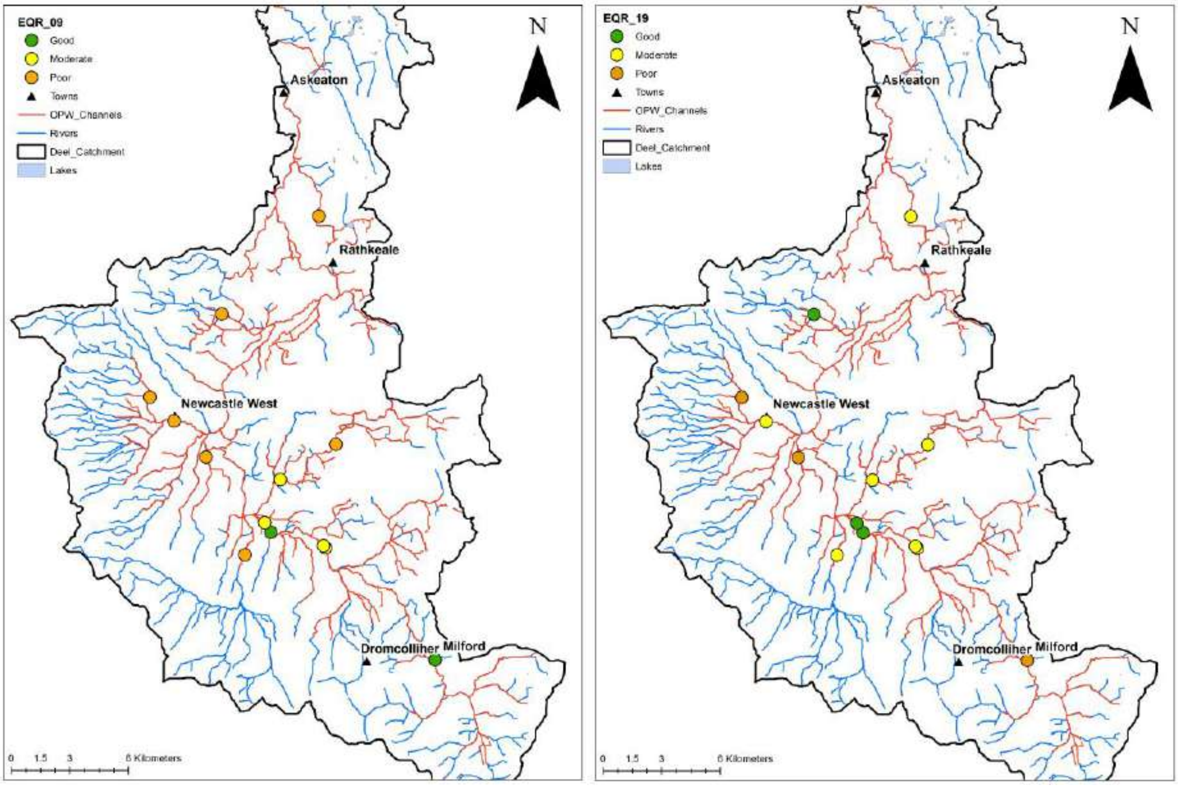


Figure 2.6 EQR results for fish from sites fished in both 2009 and 2019.

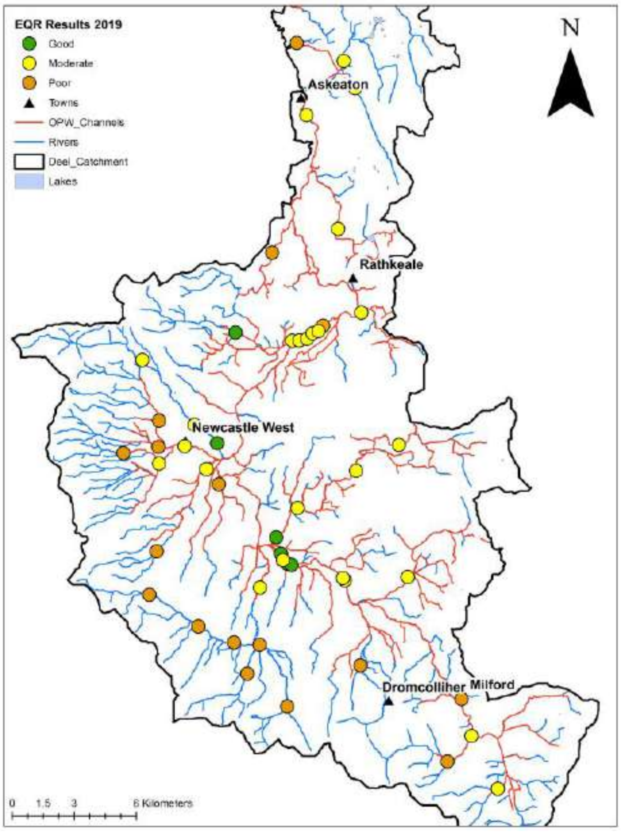


Figure 2.7 Ecological Quality Ratio (EQR) results from the Deel FPI Survey 2019.

2.3.2 Water Quality – Q-Values (2008 – 2017)

The EPA's long-term water quality investigations, using invertebrate Q-values, indicate that the water quality in the Deel Catchment has degraded somewhat from 2008 to 2017 (Figure 2.8), based on findings from 18 sites. In 2008, 33% (n=6) of sites were classified as "Good Status" whereas in 2017 only 17% of sites were categorised as Good Status. Over the 9 year period, 45% (n=8) of sites downgraded, 22% upgraded with 33% remaining the same status for both years (2008 & 2017) One site downgraded from poor status in 2008 to bad status in 2017 (Figure 2.8).

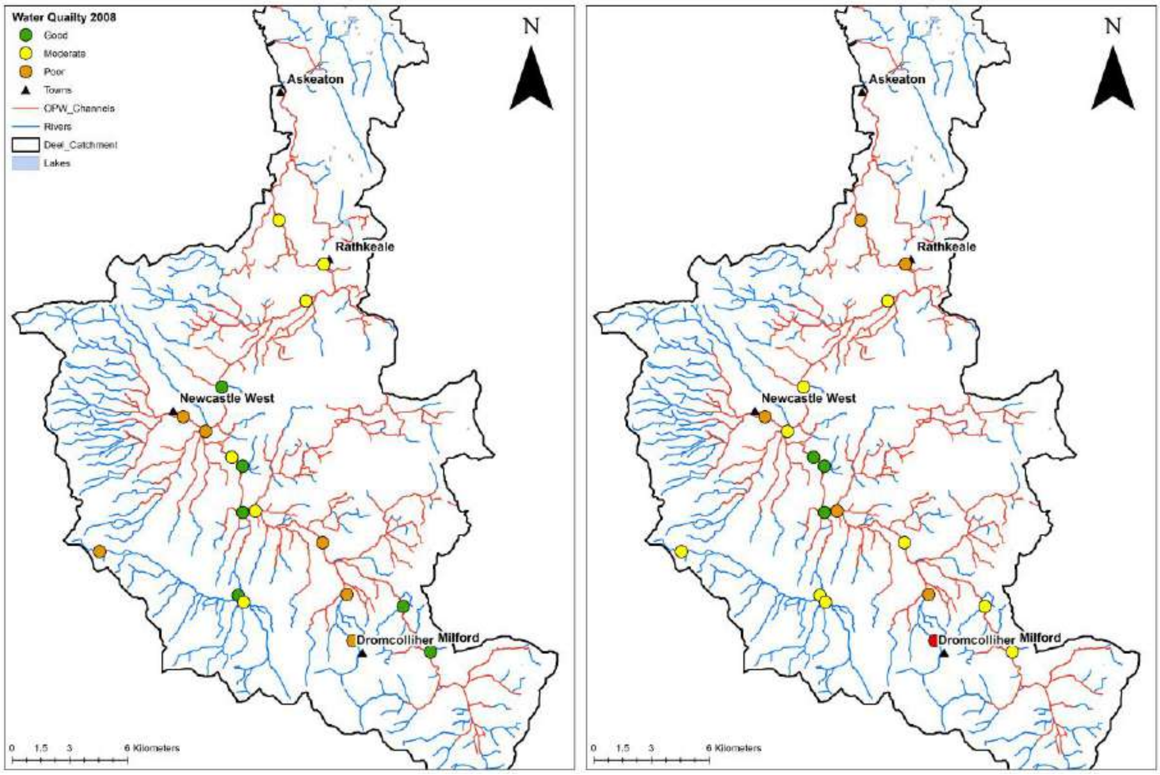


Figure 2.8 Results from EPA Q-Value (2008 and 2017) monitoring sites located in the Deel Catchment

2.4 Assessment of physical habitat using the RHAT

‘Hydromorphology’ describes the interactions of geomorphology and hydrology of a river system in space and time or more simply put, hydromorphology is the physical habitat of a river constituted by the physical form (abiotic and biotic) and flow of the river. Key elements include the flow, channel dimensions, topography, substratum, continuity and connectivity (longitudinal, lateral, vertical and temporal), sediment regimes and sediment transport and the interaction of all these components in both space and in time. Man-made features such as bank protection works, artificial barriers (weirs, dams) and modifications to processes (gravel traps) are also included in assessment of hydromorphology status.

As a “supporting element” Ireland must report directly to Europe on the hydromorphological quality of Irish Rivers. The River Hydromorphological Assessment Technique (RHAT), a tool developed specifically for WFD, is the Irish reporting method for hydromorphology. Twenty-six sites throughout the Deel catchment, covering undrained and OPW-drained channels, were surveyed for hydromorphology using the RHAT survey in 2019 (Figure 2.9). From this catchment-wide survey five sites (19%) passed the WFD minimum requirement of Good status, with 50% (13) categorised as Moderate, 27% as Poor (7) and 4% (1) classified as having a Bad status. Of those five sites with a Good status, four are not in OPW channels. They are located in small tributaries upstream in the Deel catchment. There is one site on the River Arra system which is in an OPW channel and classified as Good (Figure 2.10). Drainage and maintenance works may be a significant contributing factor for channels to be in an unsatisfactory hydromorphological condition. Equally, there may be scope to improve hydromorphological condition by implementing measures in the 10-step environmental maintenance guidance.

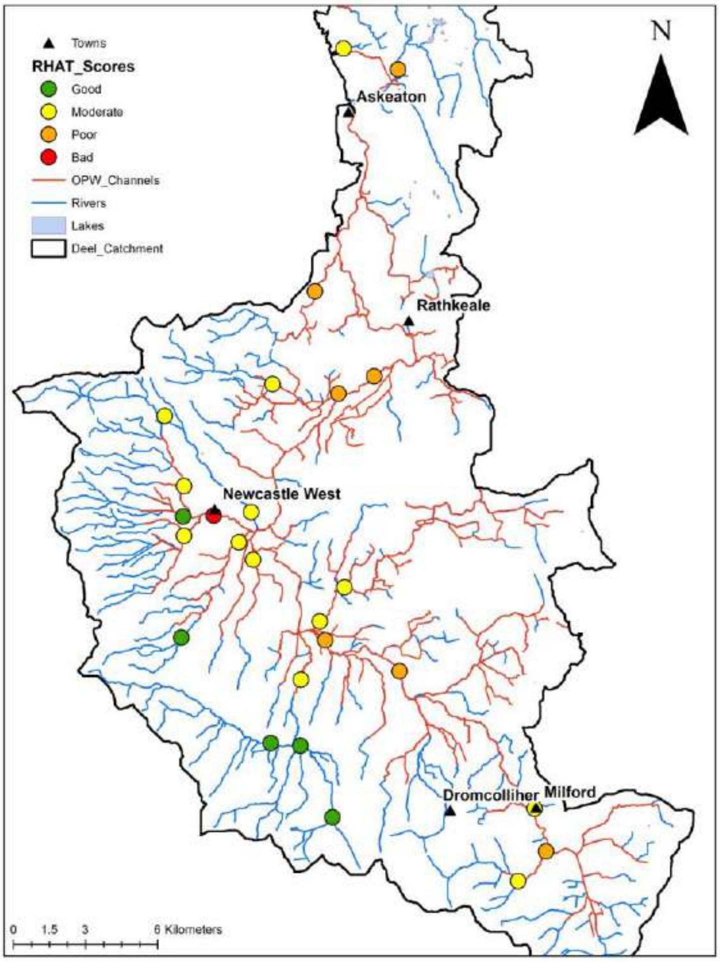


Figure 2.9 RHAT results from the Deel Basin FPI Survey 2019.

Figure 2.10 Example of a RHAT site achieving 'Good' status on the River Arra.

The overall RHAT score is developed from the individual scores given to 8 attributes, each of which is scored independently when on site (Figure 2.11). Each component is scored from 0-4, with 4 being the highest possible score given per element and all 8 are weighted equally.

When each element is broken down and averaged for the Deel dataset, the scores range between 1.15-2.25. Given that 50% of the RHAT scores in the Deel resulted in Moderate status, this distribution is not surprising. Flood Plain Connectivity and Riparian Land Cover scored the lowest, on average, with Bank Structure & Stability and absence of Barriers to Continuity scoring the highest on average. In arterially-drained catchments, it can be expected that Flood Plain Connectivity would have a low outcome, as the channel becomes isolated from the floodplain by design.

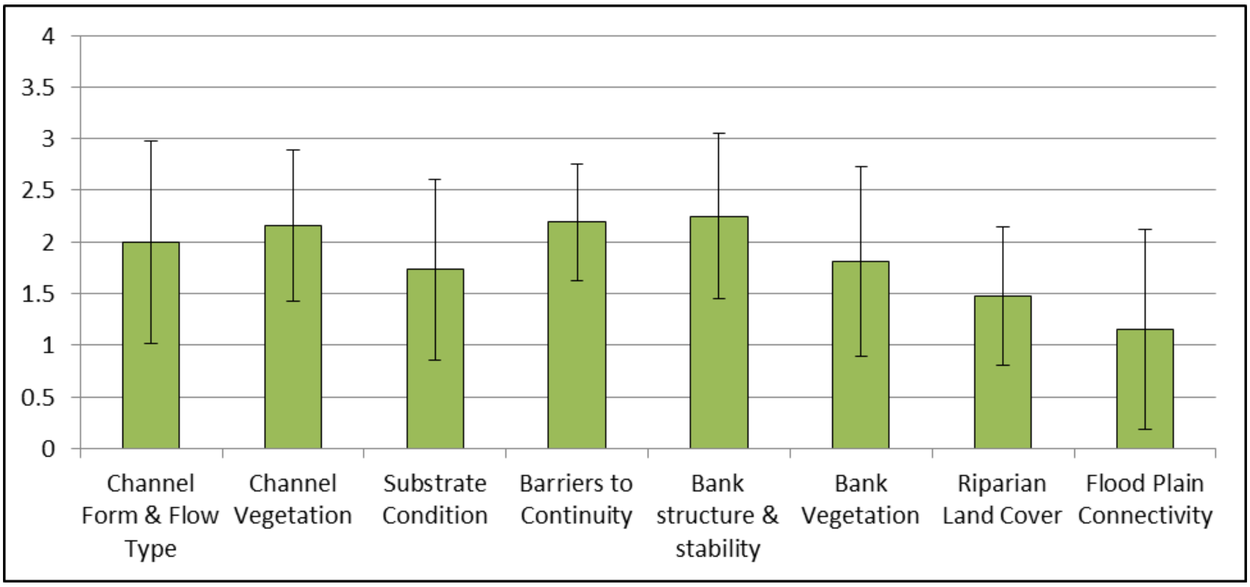


Figure 2.11 Mean and standard deviation for all 8 components of the RHAT survey in the Deel catchment (n=26).

Drainage works result in a number of significant hydromorphological changes, flood plain connectivity is interrupted, bank structure is un-natural and canopy cover is impacted. Post-drainage when the river attempts to recover its own form and function, riverine processes can lead to a more natural condition in the river with riparian and instream vegetation growth and sediment deposition but recovery can be impacted adversely by channel maintenance. Maintenance adhering to the “10-steps of environmentally friendly maintenance”, developed by OPW and IFI, may positively impact on the recovery of 5 of the 8 RHAT components and promote improvement in overall RHAT scores.

Rigorous positive implementation of the “10-Steps” has the potential to improve RHAT component scores in:

- Channel form and flow type (Step 4, 7, 8 and 10)
- Channel vegetation (Step 2 and 4)
- Substrate condition (Step 2, 3, 8, 9 and 10)
- Bank structure and stability (Step 1, 2, 5 and 6)
- Bank vegetation (Step 1, 2, 5 and 6).

The data for the eight attributes in the Deel catchment was divided into average RHAT component scores for both drained and undrained channels (Figure 2.12). There is little difference in the Riparian Land Cover or Barriers to Continuity components. For the remaining six components of the RHAT, the undrained channels achieve higher values on average than the OPW channels. The range for RHAT scores from the undrained channels varies from 2.2-3.2 compared with drained channel range of 0.9-2. It should be pointed out that the majority of the undrained sites were in small streams in the upper reaches of catchments. However, the comparison does indicate the scope to achieve higher RHAT scores in drained channels.

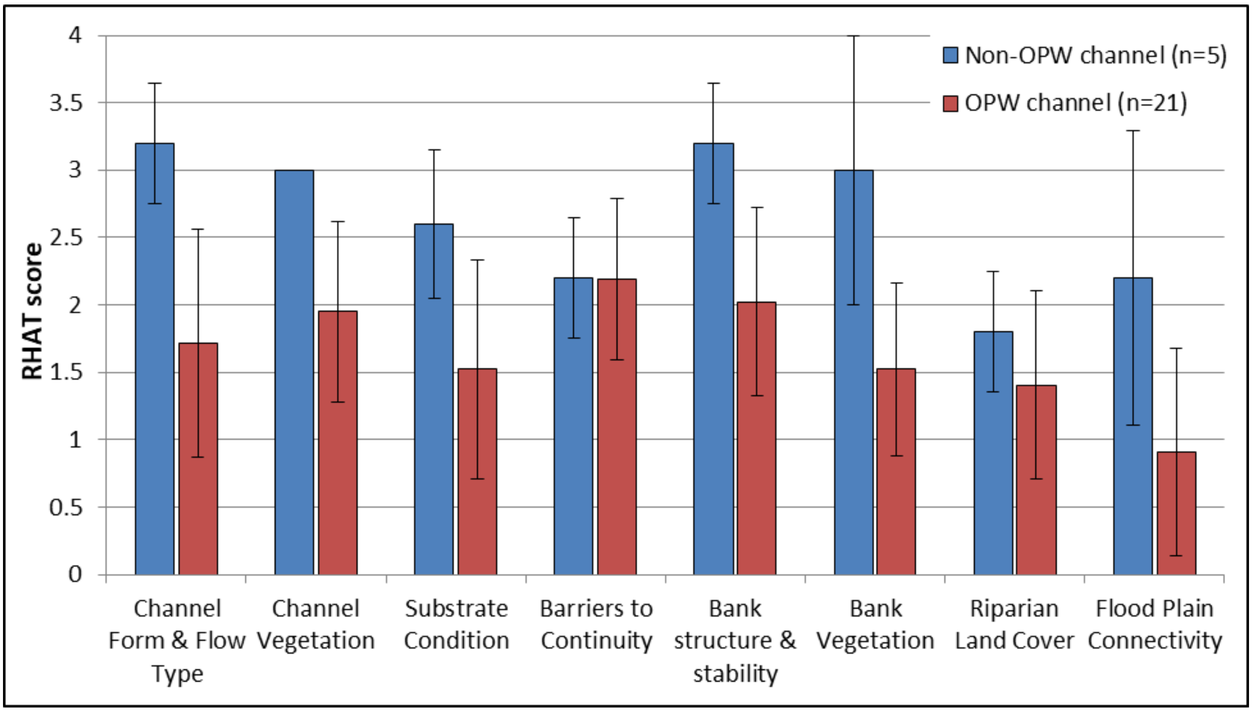


Figure 2.12 Mean and standard deviation for all 8 components of the RHAT survey, separated into undrained channels (n=5) and OPW-drained channels (n=21) for the Deel catchment.

2.4.1 RHAT comparisons in OPW catchments

RHAT surveys have been ongoing as part of the EREP survey works with concentrated catchment-wide survey efforts available since 2015 (Table 2.1).

Table 2.1 Recent catchment-wide surveys showing number of RHATs per drained and undrained channels. *The surveys in the Blackwater were completed as part of the EU INTERREG Catchment CARE project.

Year	Catchment	Area (km^2)	OPW channel	Non-OPW channel	Total
2015	Dee	389	32	0	32
2016	Bonet	418	11	16	27
2017	Inny South	593	26	0	26
2018	Inny North	631	24	1	25
2018-19*	Blackwater	394 (RoI)	10	4	14
2019	Deel	547	21	5	26
			124	**26**	**150**

There are differences in the WFD status results achieved in OPW channels (drained) compared to non-OPW channels (undrained), with a prevalence of the minimum WFD status of Good status in the latter (Figure 2.13). By comparison, the majority of RHATs in OPW scheme channels scored as either Moderate or Poor. There were only 5 instances of Good status achieved in an OPW channel from a total of 124 sites.

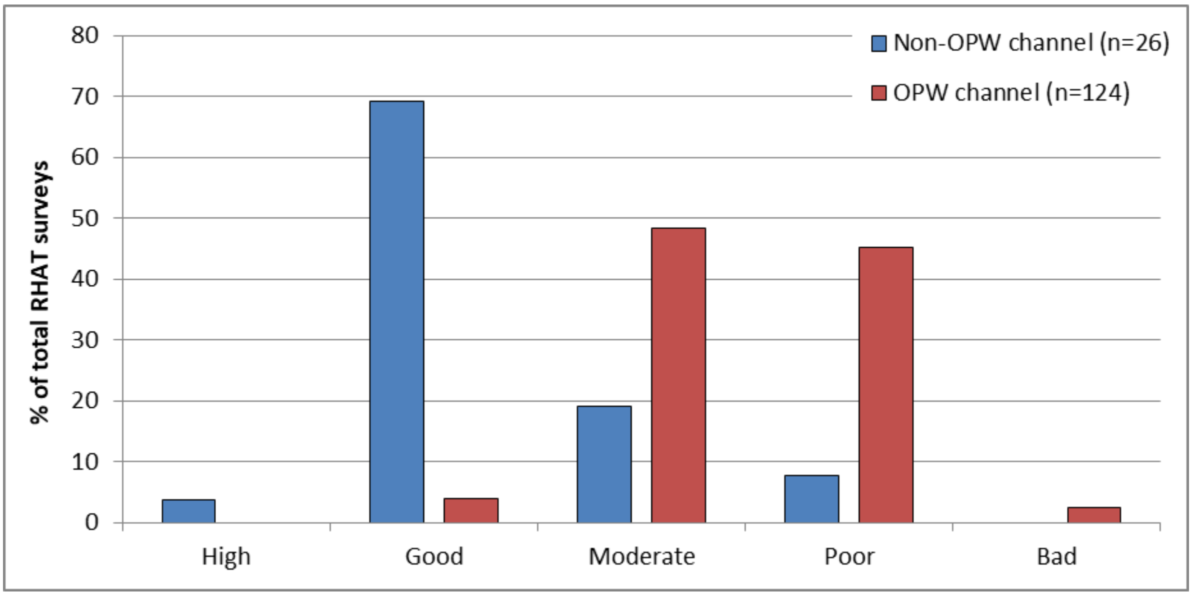


Figure 2.13 Status achieved in RHAT surveys as a percentage of the total number of surveys, separated into undrained (n=26) and drained (n=124) channels.

When the individual components of the RHAT scores from the four catchments are separated and averaged (Figure 2.14) there are clear differences in the mean scores between OPW (n=124) and non-OPW channels (n=26). The only similarity is the close result in the Barriers to Continuity component. The largest difference is in the Flood Plain Connectivity component, followed by Channel Form & Flow type.

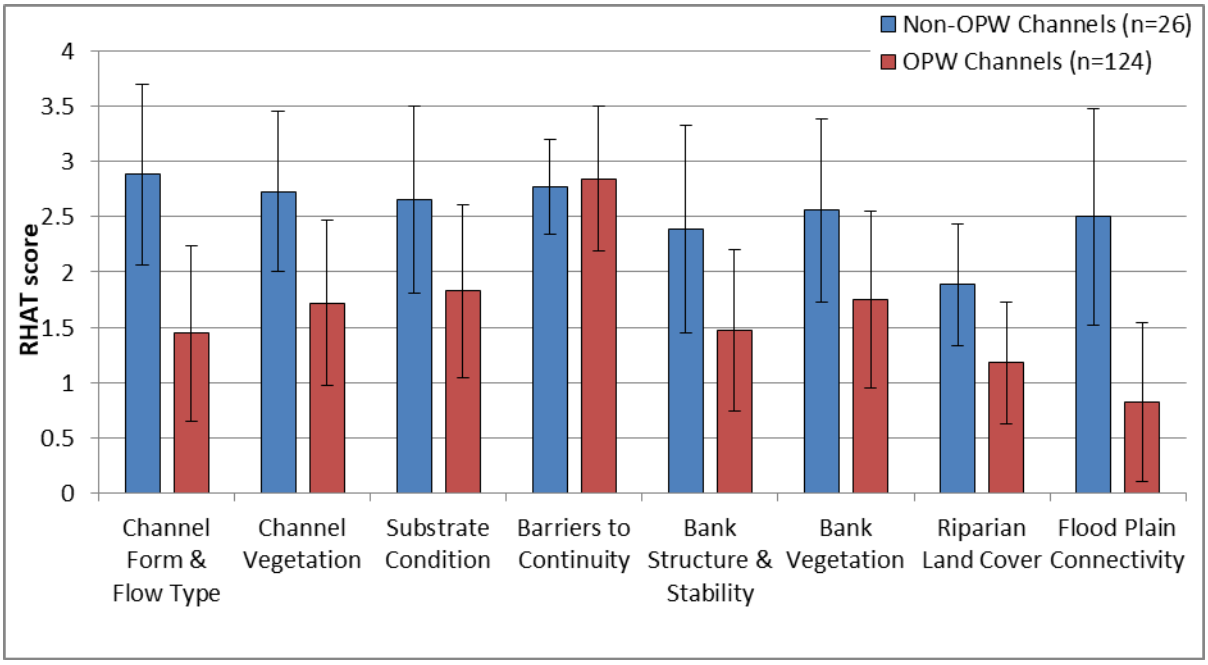


Figure 2.14 Mean and standard deviations for the 8 scoring components of the RHAT survey, separated into undrained channels (n=26) and OPW-drained channels (n=124) in the Dee, Bonet, Inny, Blackwater and Deel catchments.

Using an unpaired (independent) t-test and assuming unequal variances, the results from non-OPW channels were compared with those of OPW channels. A two-tailed test confirmed there is a significant difference ($p < 0.05$) in the means for 7 of the components, with the exception of ‘Barriers to Continuity’. For all remaining 7 components, the t-test returned small p-values ($p < 0.001$), indicating the differences in the means was signifcant for all these scoring components.

Comparing the results from the Deel survey (n=26, Figure 2.12) in the context of the overall results from OPW catchments (n=150, Figure 2.14), the outcomes are broadly similar. Of the eight scoring components of the RHAT survey, there is a trend for significant differences in all but one of the scores (Barriers to Continuity) when comparing the results generated in OPW channels versus non-OPW channels. There is potential to examine these differences and identify opportunities to improve some elements of RHAT scores in OPW channels using enhanced maintenance measures.

2.4.2 RHAT comparison to fish EQRs

When RHAT scores are compared to fish EQR scores (n=128), there is a very weak or absent correlation (Figure 2.15). When the data are divided out by catchment (Figure 2.16), it is evident that there is a lot of scatter in all of the catchment datasets. The Inny shows the stronger reationship between RHAT score and fish EQR, however that correlation is still very weak (R^2=0.14). When comparing fish EQRs to individual RHAT components, the scatter is propogated throughout all the components and any correlations were very weak or absent altogther, indicating no relationship.

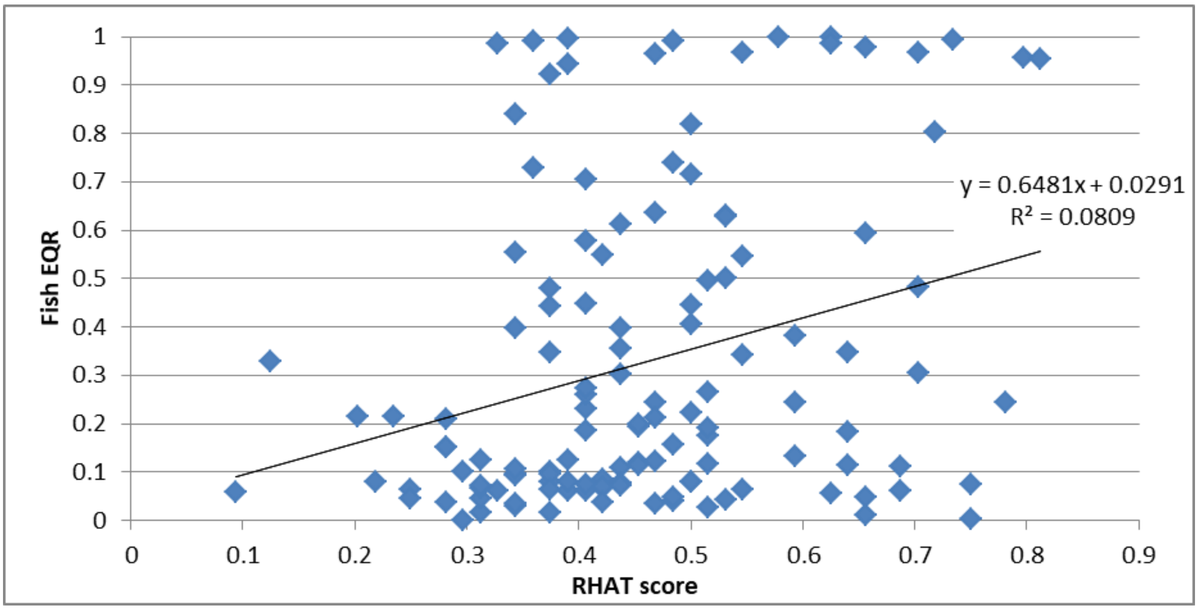


Figure 2.15 Fish EQRs compared to RHAT scores for sites in the Dee, Bonet, Inny, Blackwater and Deel catchments (n=128).

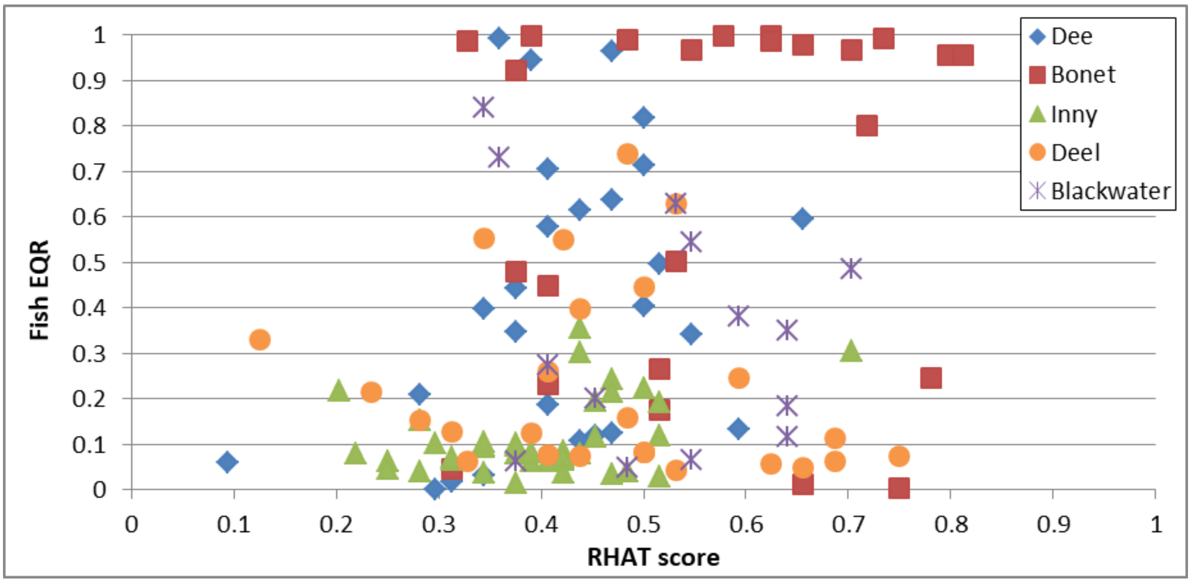


Figure 2.16 Fish EQRs compared to RHAT scores for sites in the Dee (n=26), Bonet (n=24), Inny (n=39), Blackwater (n=14) and Deel (n=25) catchments.

This exploratory analysis does not indicate any clear link between fish EQRs and RHAT scores. EQR scores are highly influenced by presence or absence of salmonids. In some catchments, such as the example outlined in the Deel, significant barriers may affect the migation pathways of diadromous species back to their spawning grounds. The habitat, as measured in the RHAT score, may have a good status, but that does not necessarily mean the fish populations will be able to access it. Further investigations are required into the nuances of the RHAT scoring matrix, and what recommendations can be made as regards to improving habiat, and therefore scores in certain RHAT components in OPW catchments.

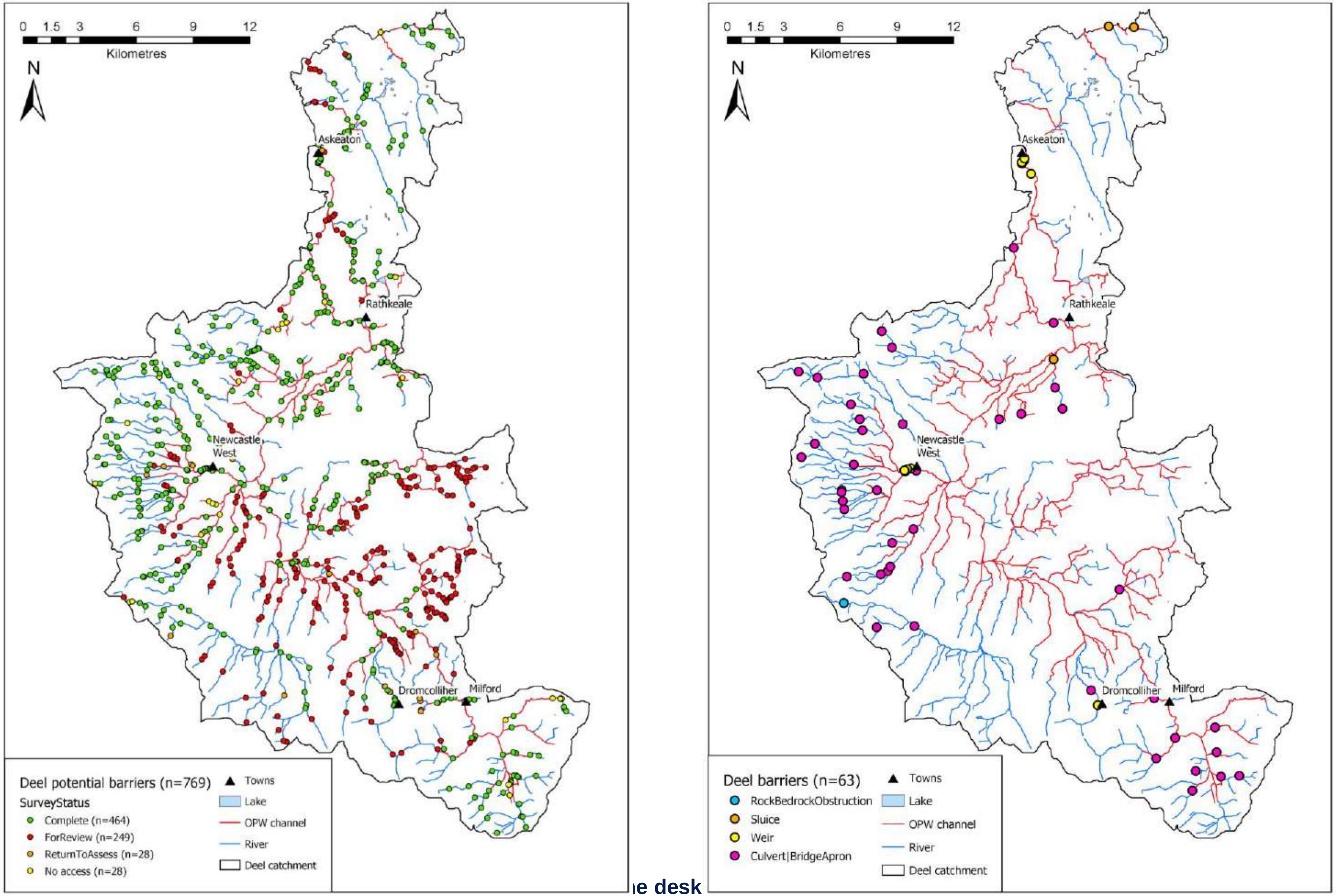
2.5 Barrier assessment: cataloguing fish passage issues

Barriers have been identified as being a major impact factor on both migratory fish, such as salmon and eel, and resident species that undertake localised movements. The issue of barriers is relevant in the WFD, in the context of hydromorphology and continuity.

A barrier assessment survey was undertaken on the Deel catchment in 2019 to identify both natural and man-made barriers to fish passage and sediment transport. This was achieved by combing a desk-based survey which identified potential barriers, using a range of datasets including historical maps and aerial imagery in GIS software, along with a field survey using a barrier assessment form, loaded onto a mobile web-mapping application on an Android tablet, developed by IFI. Throughout the Deel catchment a total of 769 potential barriers were identified during the desk based study (Figure 2.17).The survey process is intended to record man-made barriers as well as natural barriers. However, it is implicit in the WFD that natural 'barriers' should not be modified.

During the 2019 survey 464 of the 769 in-stream structures identified as potential barriers were visited and assessed. Bad weather during the latter part of the year hindered progress as potential barriers should be surveyed during low water levels. The main area of barriers which are yet to be reviewed is the section just north of Dromcolliher which includes many OPW structures. The EREP team will endeavour to complete the remainder during 2020 when water levels allow.

Of those 464 structures surveyed to date, 63 (13.5%) were assessed as barriers to fish migration and measurements of these were taken in the field (Figure 2.17, Table 2.2). Most of the problematic structures are bridge aprons or culverts (n=44), with the majority of these distributed in the lower order streams within the catchment. There were 3 sluices recorded and 1 natural barrier. A total of 15 weirs have been measured in the catchment to date. Six of these are located within 1.2km, upstream of the tidal influence at Askeaton. (Section 2.5.1, page 25). Further upstream of these weirs, there were two problematic bridge aprons on the main stem. Thereafter the remaining barriers recorded to date were in tributaries. Of the 63 obstacles hindering fish migration 15 (24%) are located on OPW channels.



the Deel catchment (left, n=769). Barriers identified during surveying (right, n =63).

Table 2.2 Barriers identified and assessed in the Deel catchment survey 2019

Structure type	Number
Culvert/ Bridge Apron	44
Ford	0
Sluice	3
Weir	15
Natural – rock/bedrock	1
Total	**63**

Structures surveyed in the field were assessed using a standardised digital assessment form. The assessment process included measurements of the channel and structure dimensions. One section of the form requires a qualitative assessment of each structure in respect of its potential to act as a barrier to particular fish species in the survey conditions. These scores are based on expert opinion of the surveyor in the field as to a fish species' ability to pass the obstruction in the channel for the water conditions on the day of the survey (which is typically low summer flow).

Barriers directly impact fish migration throughout the Deel catchment during low to medium water levels. These barriers restrict the use of upstream habitat for both resident and migratory fish species. Salmon, brown trout and lamprey species require habitat with plentiful gravels for spawning. Such habitat is generally found in the upper reaches of streams to which barriers may be blocking access.

As well as impacting fish migration, barriers influence the continuity and connectivity of the river system along with potentially adjusting natural river processes. The 63 structures identified in this survey represent habitat fragmentation and river discontinuity, altering river hydromorphology and representing a potentially reduced Water Framework Directive classification. These instream structures influence sediment transportation and the flow regime of the river, with some acting as gravel or sediment traps and others ponding water upstream of the structure. Mitigation measures to aid fish passage and sediment transport have the potential to benefit the fish communities in the channel by both granting access to previously unreachable sections and by providing downstream dispersal of spawning substrate via sediment transport.

IFI has generated a GIS layer of the structures acting as barriers in the Deel, as surveyed during 2019, highlighting those which are OPW structures (Figure 2.18). This layer should inform OPW personnel in planning maintenance work on channels in the Deel system. It is considered that many of the barriers identified and the problems they create, in a Water Framework Directive context, can be addressed by mitigation measures implemented during maintenance.

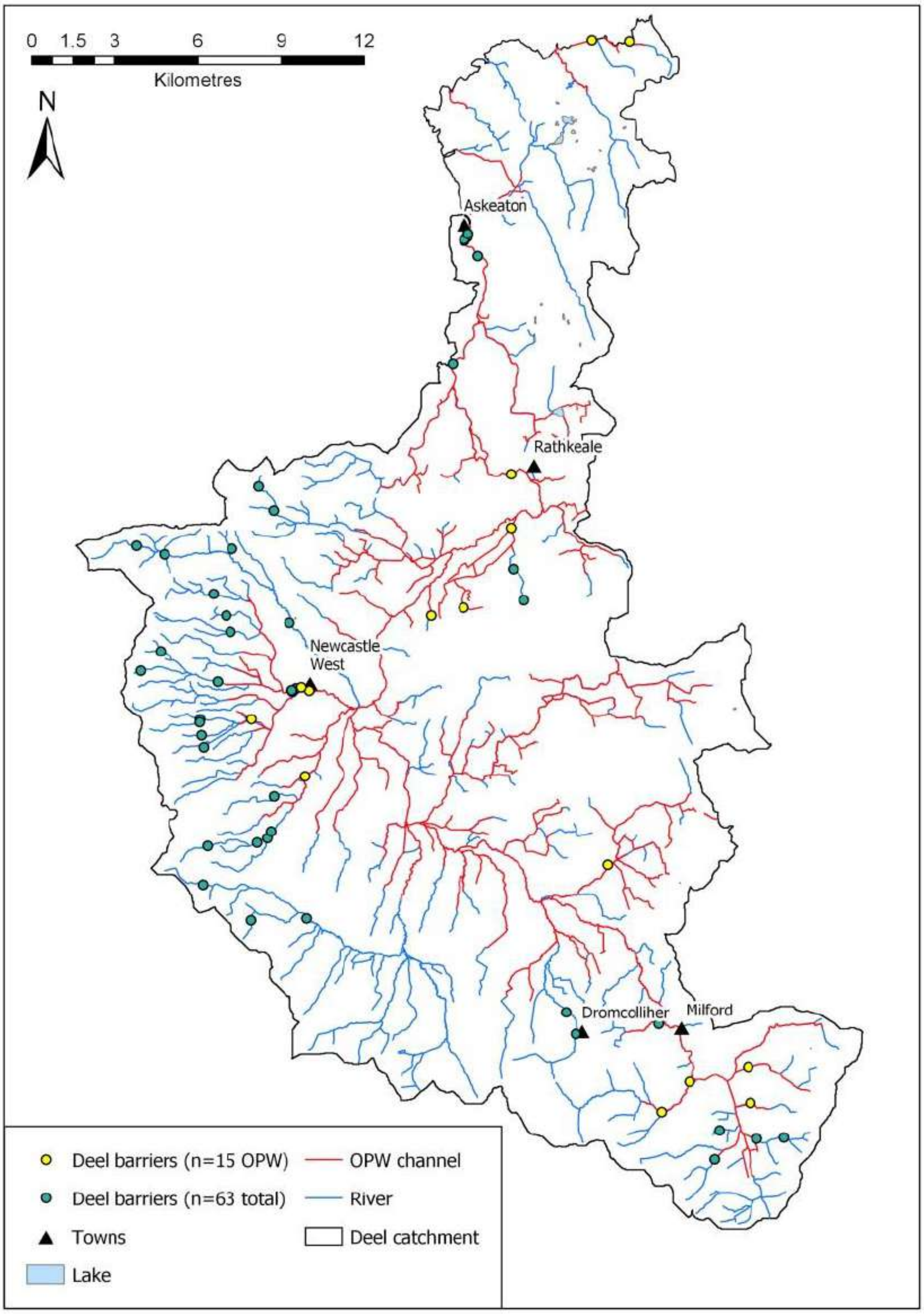


Figure 2.18 Map displaying locations of all barriers assessed in the Deel catchment with OPW structures identified

Figure 2.19 Examples of barriers identified during the Deel survey, including a box culvert, bridge apron, pipe culvert and small weir.

IFI is proposing that a selection of the barriers identified on the Deel should be examined in 2020 by the resident engineers and foremen of OPW with relevant IFI personnel with a view to agreeing on mitigation strategies that can be implemented cost-effectively by OPW during maintenance work. It is envisaged that some of these mitigations would be implemented in 2020. This would provide a template for OPW to roll out to its personnel in other drainage schemes.

2.5.1 SNIFFER survey of structures in the R. Deel in Askeaton

As part of the 2019 survey programme, a series of six weirs in Askeaton were surveyed by the EREP team working with IFI's National Barriers Programme team. These surveys used the Level II barrier assessment method employed by IFI - the WFD 111 method, developed by SNIFFER (Scotland and Northern Ireland Forum for Environmental Research), in July 2019. This methodology involves examining the structure for the number of possible routes various fish species could pass over, in both upstream and downstream directions. Thereafter each route or 'transversal' is assessed using a series of criteria including water velocity; depth of water; head loss; obstacle height; length of slope; presence/absence of a plunge pool and flow type. Based on these combined criteria, a 'barrier passability' score is generated for individual fish species or their life stage. All values generated are specific to the date of the survey and river conditions at the time.

On the day of survey, this series of structures presented as a complete upstream barrier to adult salmon, adult trout, cyprinids, adult lamprey and juvenile salmonid passage. Migrating juvenile eels would make passage on wet climbing substrate at the edges of each structure. Each structure poses different challenges for fish migration (Figure 2.21). Overall, large vertical hydraulic heads, shallow water depths over structures and high levels of turbulence were the most impinging factors on fish passage. Adult lampreys are heavily impacted by all structures in the Askeaton weir complex with five structures being complete barriers to their passage. Adult salmonids are significantly impacted by Askeaton 3, 5 and 6 (Figure 2.20).

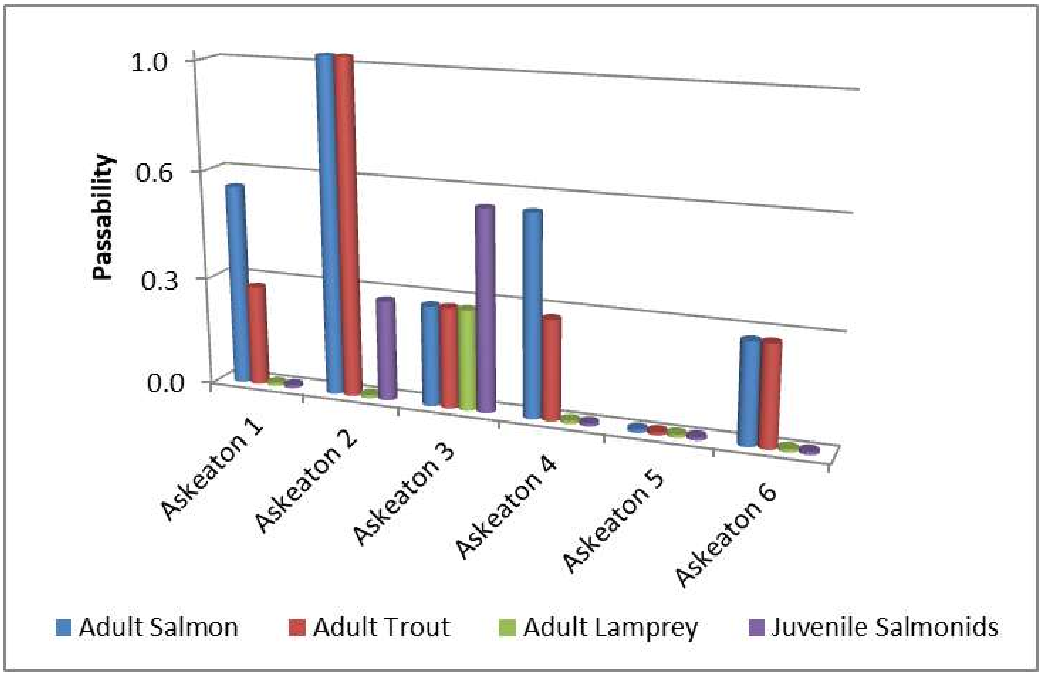


Figure 2.20 Passability assessment for the six structures in Askeaton on the River Deel. The 0-1 range is a passabililty scale. 0-Complete Barrier; 0.3-Partial high impact barrier; 0.6-Partial low impact barrier; 1-Passable Barrier.

This series of structures represents a significant hydromorphological pressure in the Deel catchment, preventing the free migration of keystone fish species. The free passage of migratory species - salmon, sea trout, eel and lamprey is fundamental in achieving ‘Good’ ecological status for the Water Framework Directive as their absence represents a deviation from reference conditions.

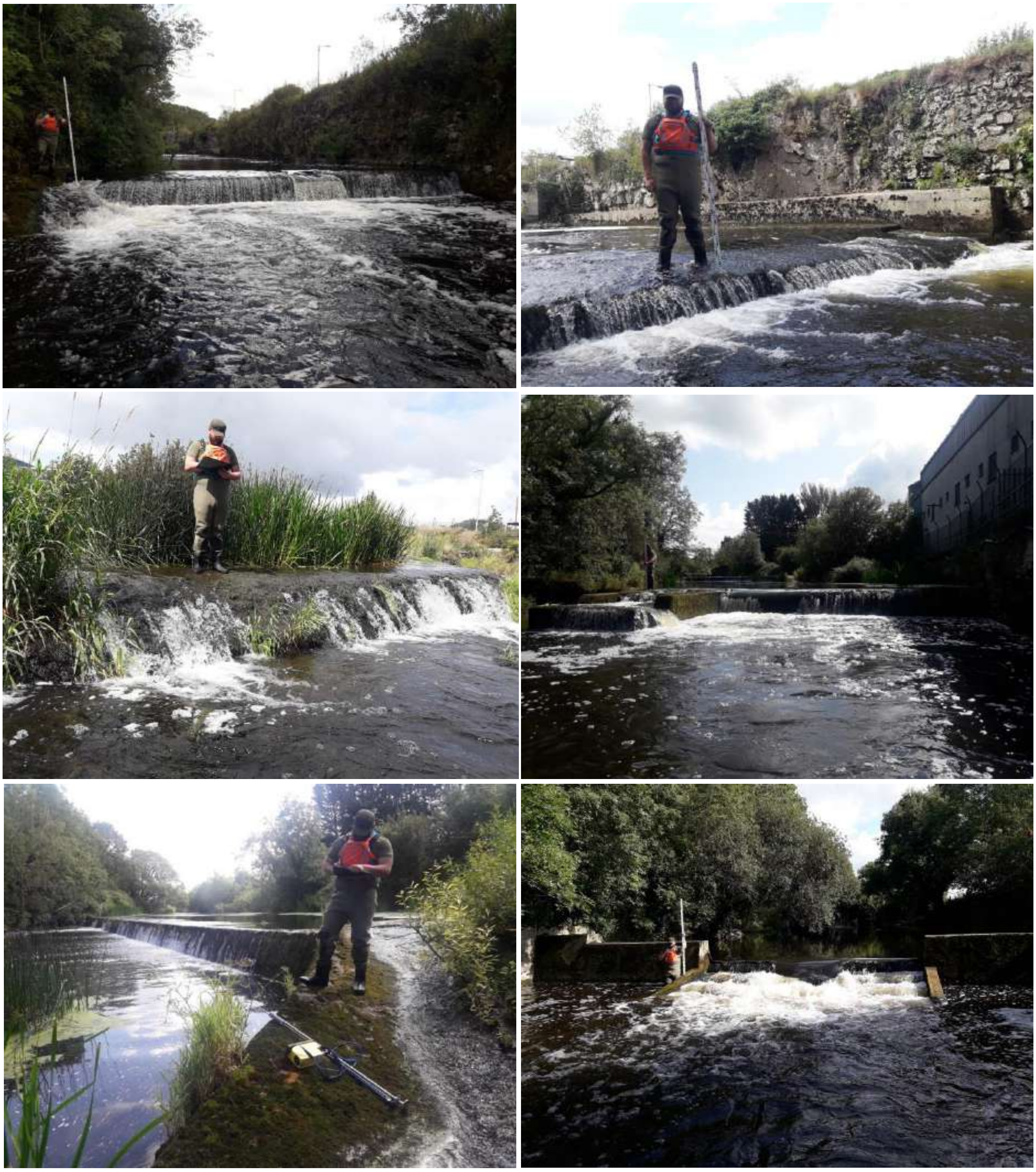


Figure 2.21 Askeaton weirs presenting barriers to migrating fish. Top row (1-2); middle (3-4); bottom (5-6).

3 Long-term study I: Enfield Blackwater (Capital Works)

3.1 Background

The Enfield Blackwater is a fourth order tributary of the Boyne. It is 25.4km in length and drains an area of 126.8km^2. The initial study commenced on the Enfield Blackwater River (OPW channel reference C1/36) in 2009 and continued into 2010. Two sections of the channel, with differing gradient, were selected for Capital Works under the EREP study. The Capital Works process is one where materials are imported onto the site to 'construct' instream structures of a type and design that will interact positively with the available flow to bring about a long-term diversity in the channel flow and form. The Capital Works process differs from that of Enhanced Maintenance, where site alterations are undertaken using available OPW machinery and available site attributes – suitable bed material for over-digging, stone material in spoil lines etc.

In addition to the two sites selected for experimental works, a control site in an area of channel upstream, with similar physical habitat and flow type, was also selected for monitoring. The sections of river selected for works were surveyed for fish community and physical habitat prior to the commencement of any enhancement works in 2009. The 2019 study aimed to repeat the fish and physical habitat studies of 2009-10 and thereby establish this set of sites as one for long-term monitoring. This would allow, over time, an assessment of the impact of the physical works programme on the physical attributes of the river sections as well as an assessment of the use of the new habitats by the dominant fish species – brown trout and Atlantic salmon. Both experimental sites were accessible, courtesy of local landowners, in 2019. However, the original control site was rendered unfishable due to debris blockage and fallen trees. An adjacent site of similar character, within 200m of the original, was selected in 2019 as an alternative. This new control site had the same channel dimensions and form as the previous site. The three sites were designated as follows (Figure 3.1):

- Control site (d/s old N4 bridge)
- Experimental site 1 (Exp.1) - (u/s of Castlerickard bridge)
- Experimental site 2 (Exp.2) - (u/s of Rourkestown bridge)

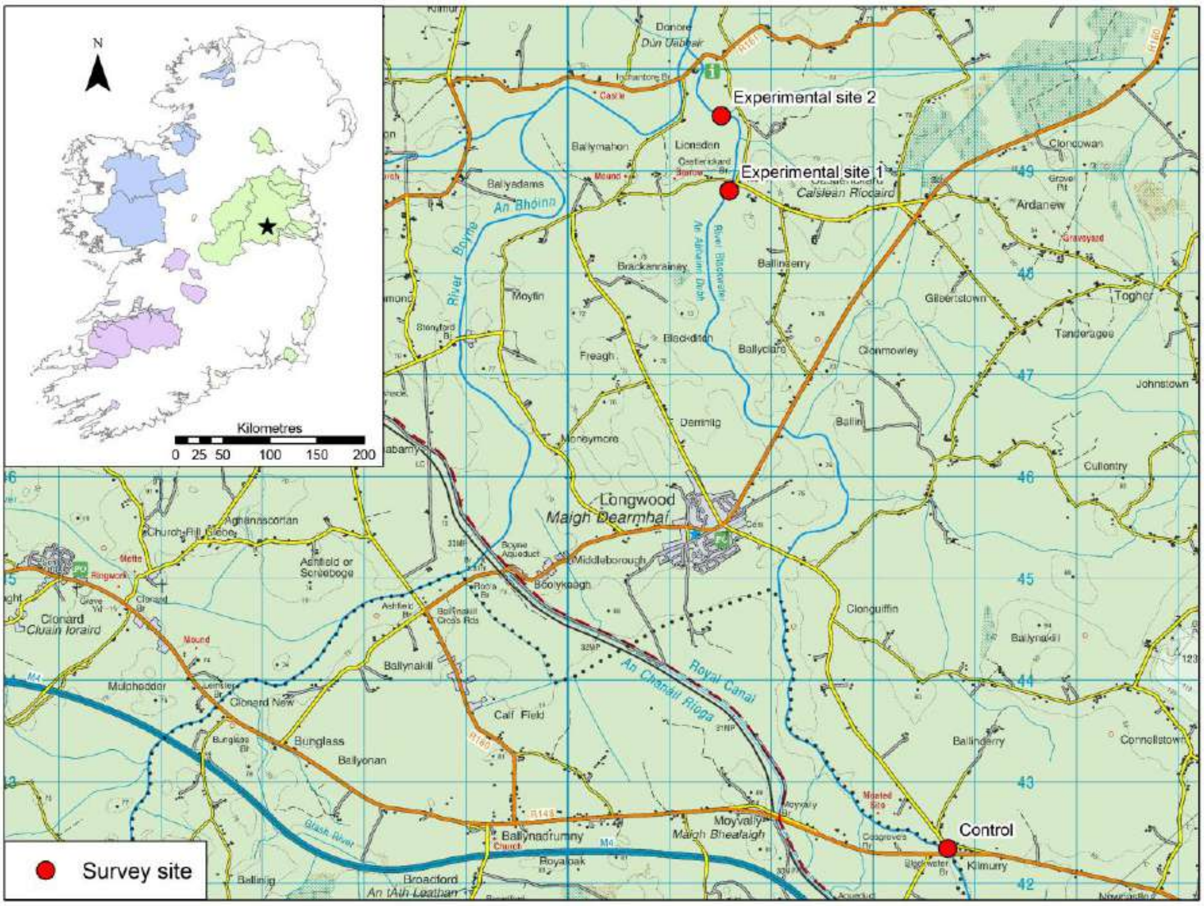


Figure 3.1 The Enfield Blackwater is located in the Boyne catchment in the OPW east region (inset). The map shows the locations of the study sites along the Enfield Blackwater.

Capital works

The following measures were implemented as Capital Works:

- Control: remained untouched with no enhancement works completed on site.
- The capital works at Exp.1 involved the construction of three paired deflector/pool complexes upstream of Castlerickard Bridge, in 2009 (Figure 3.2). Their primary function is to constrict the flow locally, thereby increasing velocity into the downstream pool. These deflectors were constructed on defined gradient break points to maximise the velocity. A number of alternating deflectors were also built to increase water velocities through this site. These alternating deflectors were not coupled with excavation of a thalweg or line of deepest flow. One aim of using the alternating deflectors was that they themselves would help in forcing the channel into scouring a line of deepest flow.

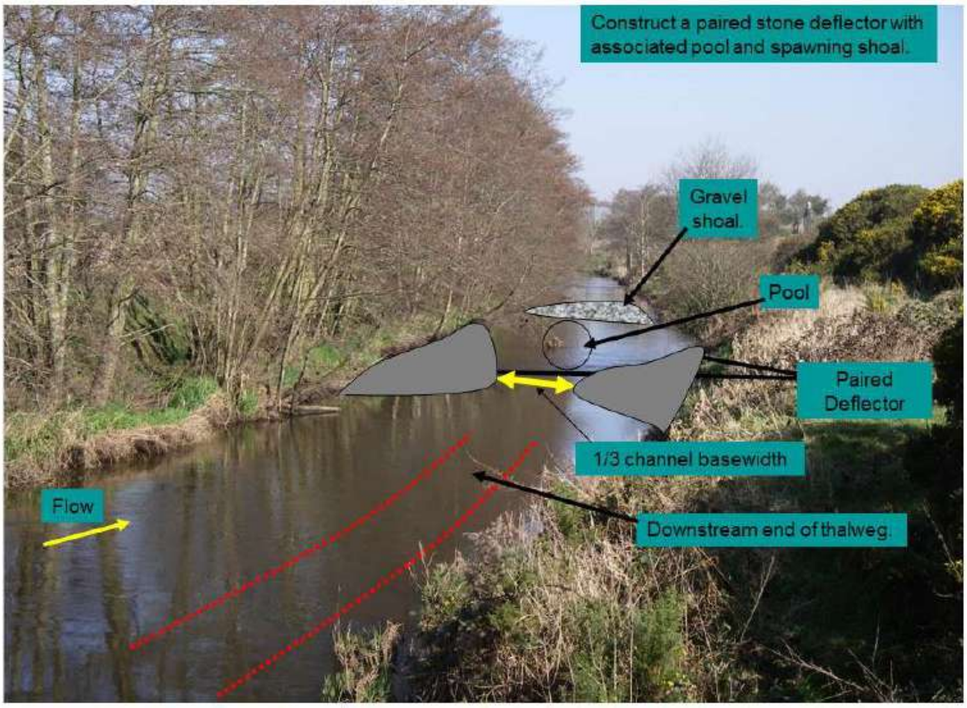


Figure 3.2 Extract from the original capital works plans proposed for a section of Experimental site 1.

- The capital works measures at Exp.2 upstream of Rourkestown Bridge, in 2010 involved construction of two spawning gravel shoals/pool complexes coupled with a series of alternating deflectors and thalweg excavation (Figure 3.3).

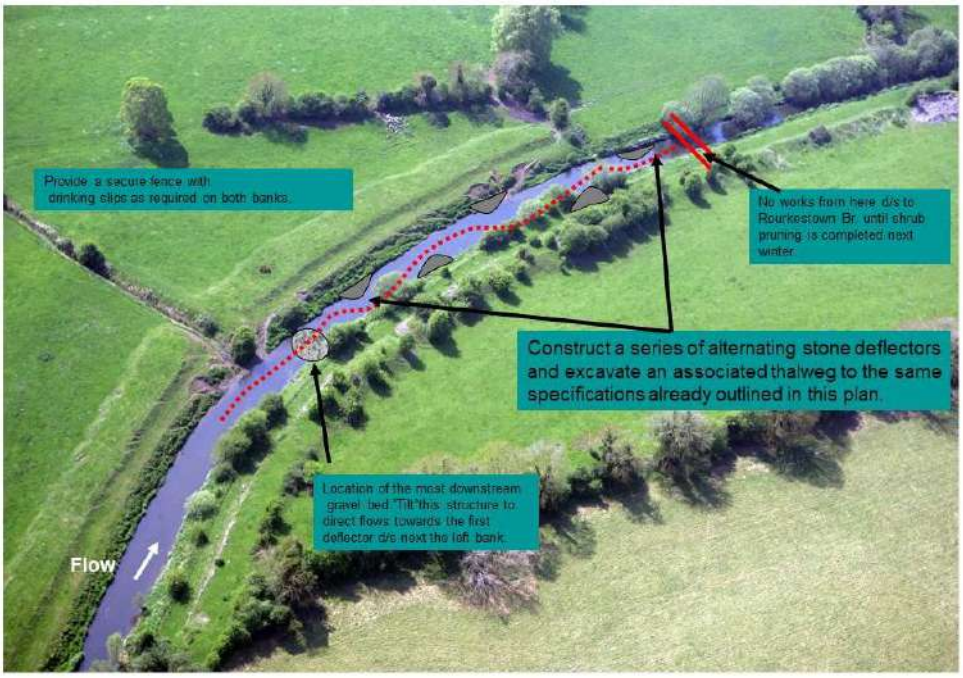


Figure 3.3 Extract from the original capital works plans proposed for Experimental site 2.

The survey sites for the two experimental strategies were nested inside the larger area of works in each case i.e. the extent of the Capital Works plans executed was greater than the actual areas surveyed for habitat and fish in 2009 and subsequent years. An additional short segment of Capital Works was designed for downstream of Rourkestown Bridge, as far as the confluence with the River Boyne, but this phase was not implemented.

3.2 Survey

3.2.1 Physical measurements

Surveys undertaken over the three years (2009, 2010 and 2019) included:

1. Longitudinal profiles of the river bed generated from levelling surveys;
2. Width-depth measurements along full site length at 5m intervals;
3. Representative cross sections with depth-velocity profiles
4. Depth-velocity profiles at locations where specific works were undertaken. In each case a series of paired depth-velocity readings were taken across a specific transect – 13 evenly-spaced locations across the wetted width of the channel. Velocity was recorded at 0.6 of depth.

3.2.2 Fishing

All sites in all years were surveyed using boat-based electric fishing gear. The fishing zones were isolated with weighted stop nets at both ends and depletion fishing was undertaken. The fish collected in each pass were processed separately and stored in bins of cool water for release on-site following completion of the electric fishing. The target species were brown trout and Atlantic salmon but fish of all species were collected, recorded and measured.

3.3 Results

3.3.1 Longitudinal profile of study sites

A longitudinal profile of each site was generated for 2009 pre-works (Figure 3.4). This shows the river bed and its characteristics before the completion of any capital works activities by the OPW.

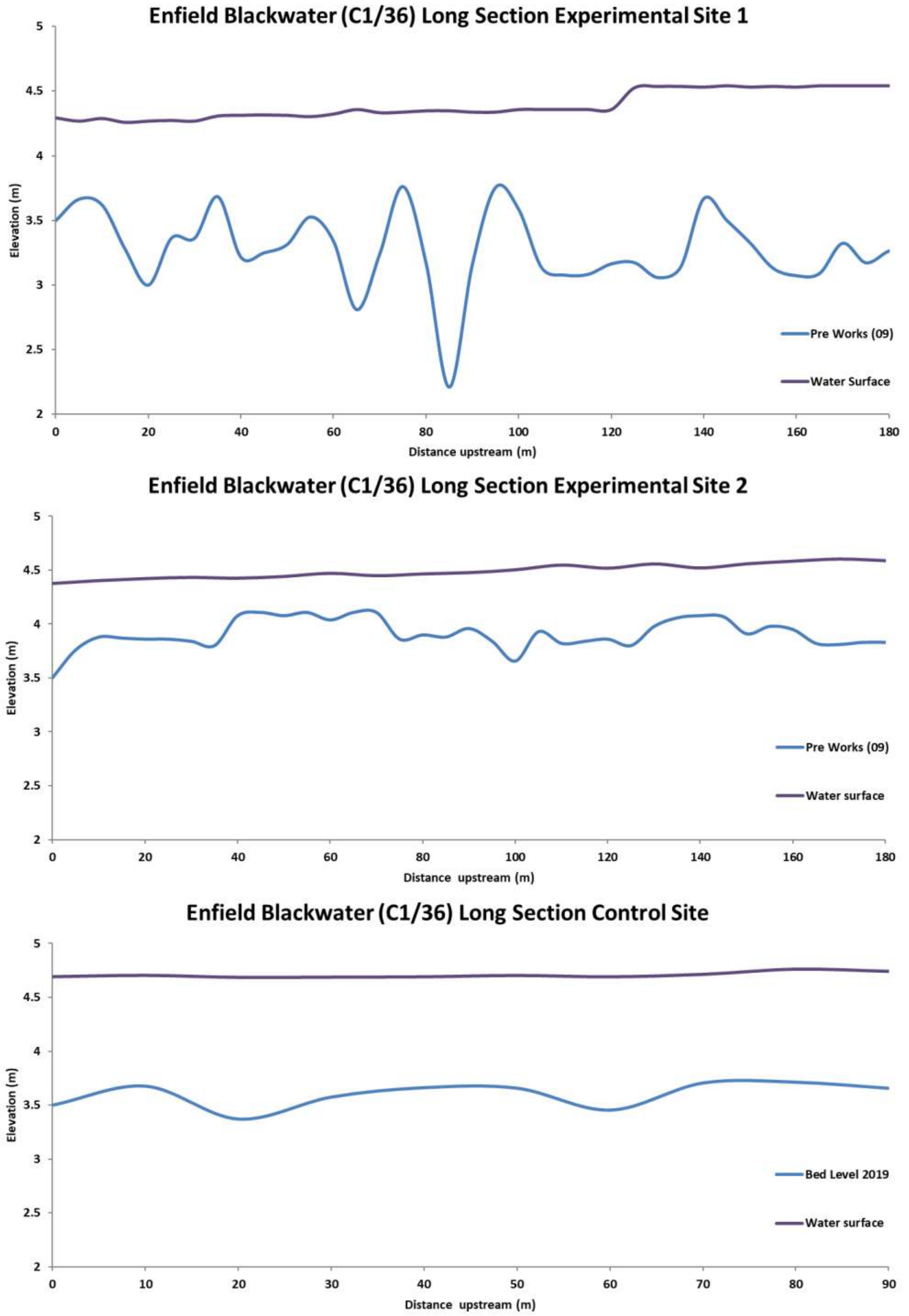
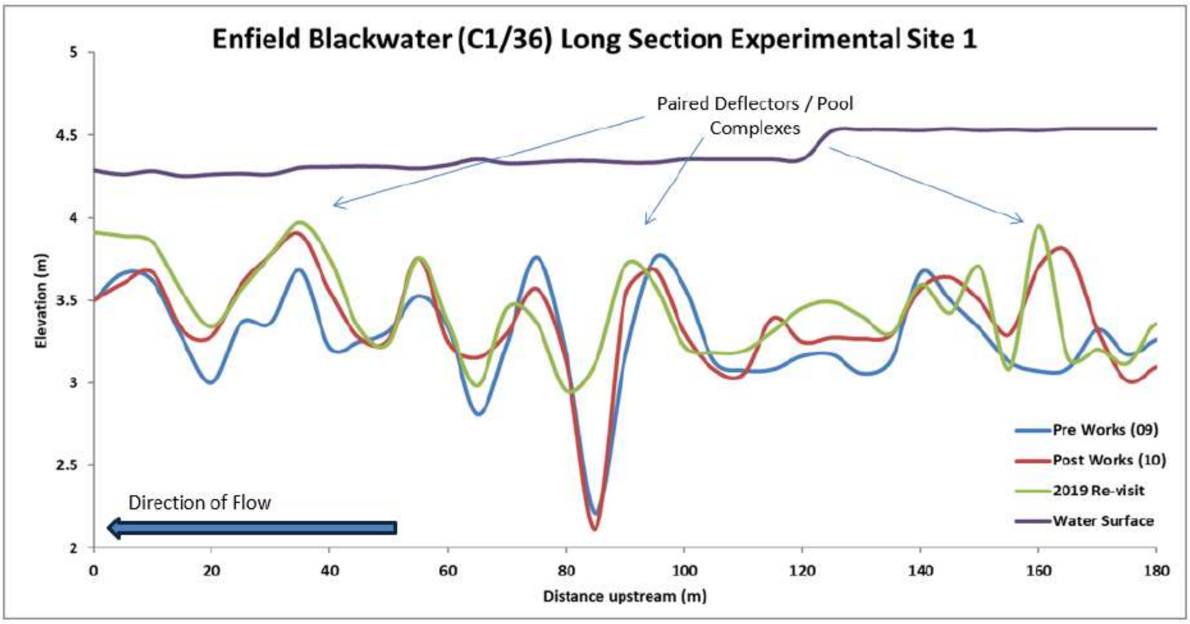


Figure 3.4 Longitudinal profile for Experimental site 1 (top); Experimental site 2 (middle) in 2009, prior to works completed. Longitudinal profile for the site selected as a control (bottom) in 2019.

The outcomes of the levelling surveys of channel long sections for each year indicate the nature and impact of the initial Capital Works between 2009-2020 and long-term outlook from the 2019 survey (Figure 3.5).



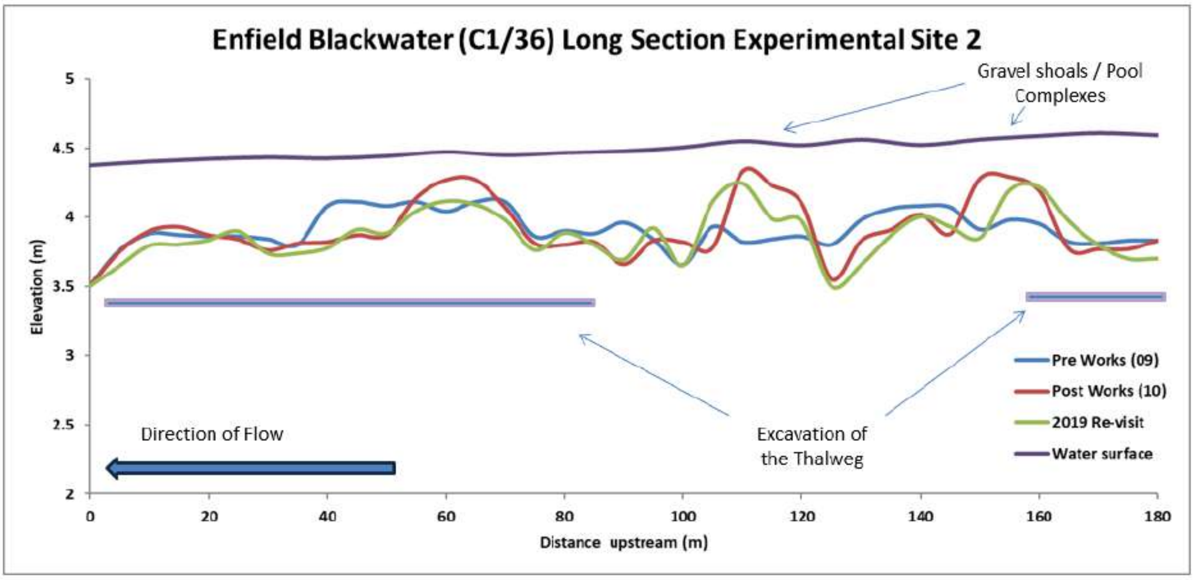


Figure 3.5 Long sections from the two experimental sites on the Enfield Blackwater, pre- and post- works along with re-surveyed results from 2019.

Experimental site 1 (Exp.1) had a very low bed gradient value of 0.04%, based on the OPW scheme design. It had a very complex longitudinal profile when levelled in detail in 2009 (Figure 3.5) with a series of shallower locations of 0.5m alternating with deeper pools to 2.0m depth. The construction of a series of paired deflectors created local accelerated velocities into the downstream pool areas and this was clearly visible in 2019. The deflectors led initially to local elevations of existing bed high points, as designed, and these alterations remained stable over the intervening period up to 2019 (Figure 3.5).

Experimental site 2 (Exp.2) had a higher bed gradient (0.1%) than Exp.1 and the gradient was of a scale that facilitates greater 'interaction' between flow and channel bed and banks. The more 'intrusive' strategy here, of introducing elevated beds of spawning gravels, was considered appropriate given the available gradient. The alterations to the bed longitudinal profile were evident after completion of Capital Works and these alterations remained in place in 2019, 10 years after works (Figure 3.5 & Figure 3.6). The alterations included (a) local elevated points where the gravel beds were placed and (b) bed deepening immediately downstream. This latter may be a result of excavation at the time of works or may be a consequence of natural bed processes, with elevated velocities over the shallow areas flowing into the deeper areas.

3.3.2 Width–Depth measurements

Using the programme 3DField, 'heat maps' were generated using wetted width and water depth measurements recorded when on-site as part of the physical surveying pre- and post-works. The same physical measurements were collected during the re-visit in 2019. Examining the contour lines in Figure 3.6 it is obvious that the Exp.2 comprised a greater variety of depths in 2010 after capital works measures were implemented. The red boxes outline the locations of the rubble mats added to the river bed. When comparing heat map 2 with 3, the rubble mats remained intact in 2019, with this section remaining shallower than the pools directly upstream. It is also apparent that the rubble mat areas are shallower than when constructed in 2009.

The purple line indicates where the thalweg was over-deepened during the works (Figure 3.6). This thalweg is still evident in 2019 with minor shifts from left to right which can be expected in an artificially confined channel. Over-deepening of the channel encourages natural processes within the riverine system including erosion and deposition along with improving the sinuosity of the channel. Evidence of such natural processes may be seen in a loss of depth between T0 and T40 but a greater development of depth between T70 and T100 (Figure 3.6).

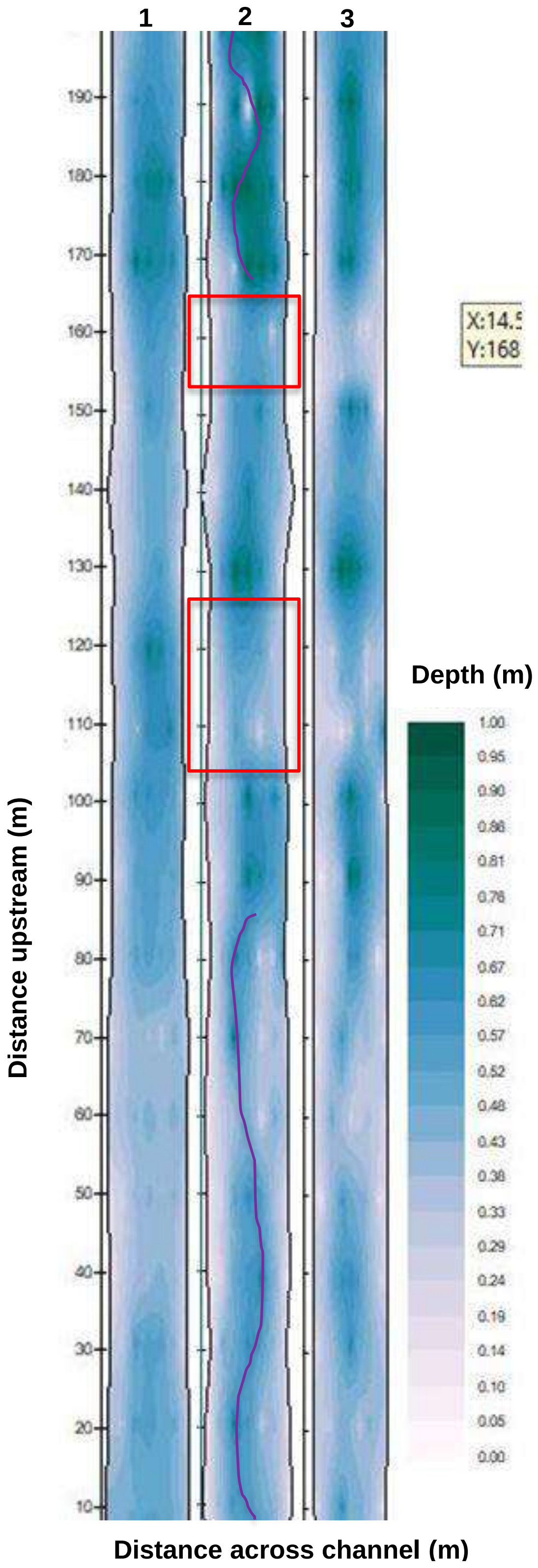


Figure 3.6 Variations in depth pre- (1) and post- (2) capital works at Experimental site 2, (upstream of Rourkestown Bridge) and depths recorded in 2019 (3). Red boxes indicate spawning gravel shoals, purple line is the thalweg constructed through the alternating deflectors.

3.3.3 Cross-sections

Cross sections were taken at selected locations across each site surveyed (Control, Exp.1 & Exp.2). This section of the report details examples of two cross sections which were located in Exp.1 at T34 and T120 of the site (T meaning transect and x meters u/s from bottom of site). Each cross-section is accompanied by a photo.

T34: This cross-section was completed at a shallow uniform section of channel in Exp.1, where no work was undertaken. The high bank tops indicate the extent of alterations and over-deepening during the initial drainage scheme of 1969-86 (Figure 3.7). In the cross-sectional profile, there is evidence of a berm on the right-hand bank, which is also obvious in the photo, densely covered in vegetation.

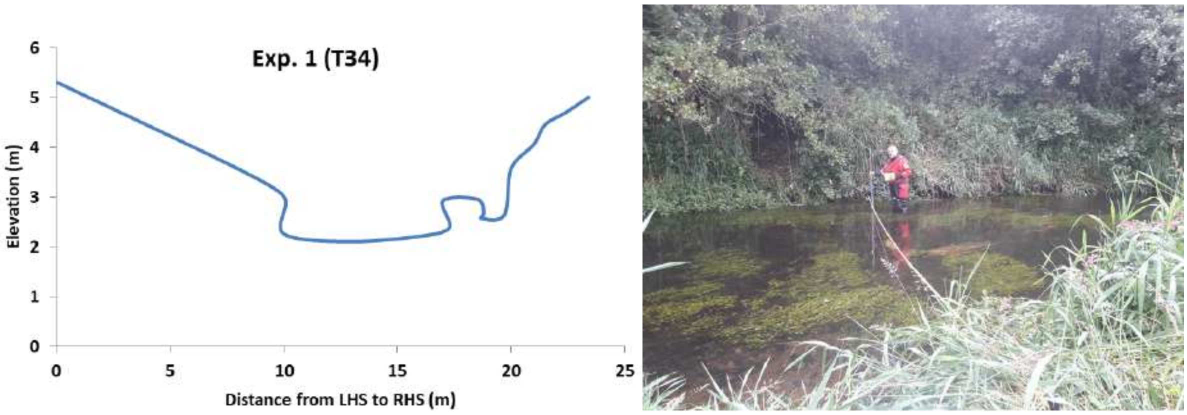


Figure 3.7 Cross-section taken at T34 (left). Photo taken at T34 (LHS) of Experimental site 1 (right).

A depth-velocity profile was generated for this site (Figure 3.8). The profile shows that peak velocity (0.5m/s) was mid channel at the deepest (0.4m) point across the channel. The velocity is relatively slower at each bank due to friction between the river and its banks.

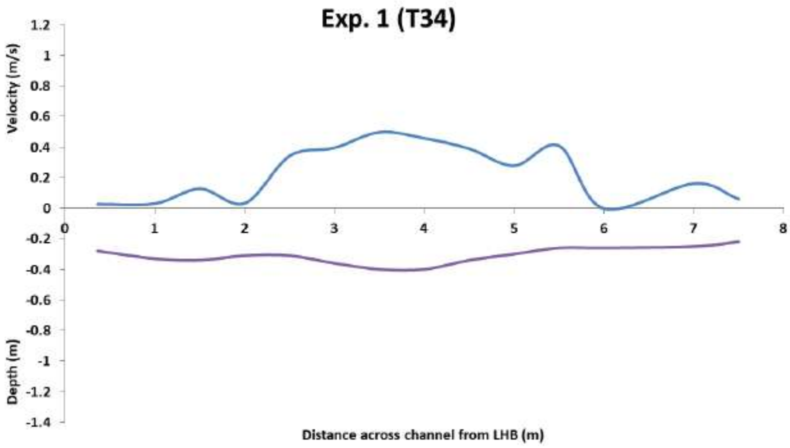


Figure 3.8 Depth-velocity profile of uniform shallows located at T34 in Experimental site 1.

T120: At Exp.1, T120 a single deflector was introduced on RHS in 2010 as part of the Capital Works plans. The structure, located on the left hand side of the channel and now growing a stand of the tall emergent grass *Phalaris*, is evident from both the cross-sectional profile and the photo (Figure 3.9). This deflector constructed in 2010 has since been incorporated into the instream channel form and is densely covered with marginal vegetation. There was also evidence in 2019 of the channel beginning to cut in behind the stone of the deflector.

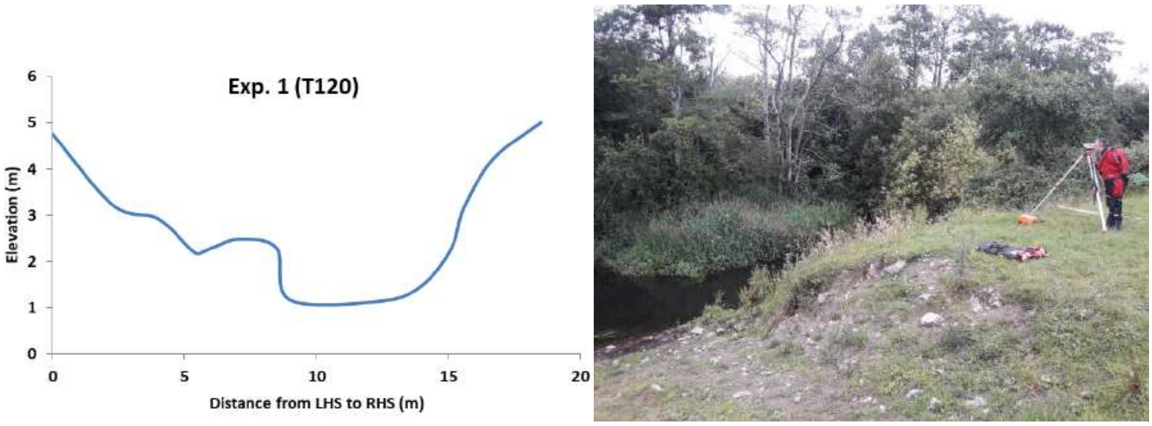


Figure 3.9 Cross-section taken at T120 (left). Photo looking d/s at single deflector on LHB located at T120 in Experimental site 1 (right).

The depth-velocity profile at T120 (Figure 3.10) indicates that the velocities increase slightly at the outlet of the deflector near the channel mid-point. The depths are shallower at the inlet and increase at the middle and outlet of the deflector.

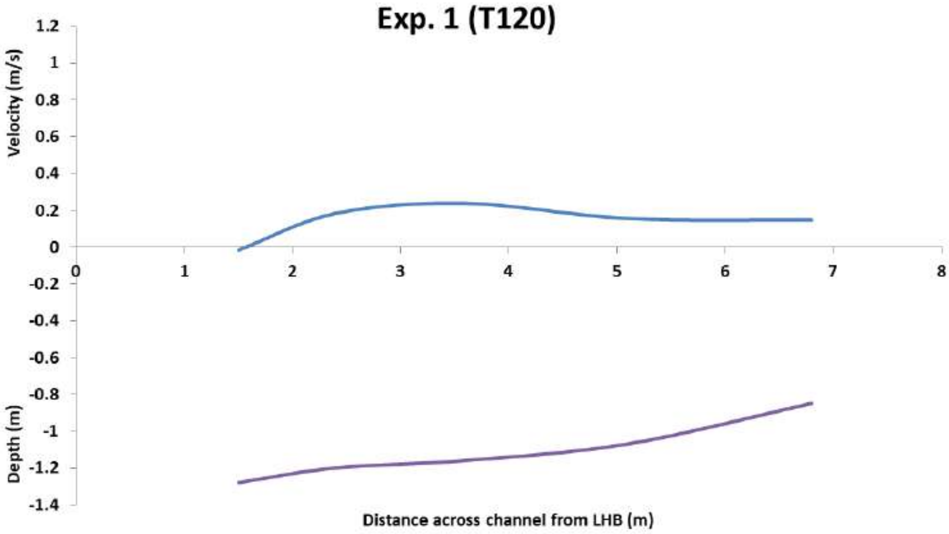


Figure 3.10 Depth-velocity profile of a single deflector located at T120 in Experimental site 1.

3.3.4 Depth-Velocity Profiles

Velocities and depths were recorded at the inlet, midpoint and outlet of a variety of structures constructed in the channel as part of the Capital Works programme. Such structures include: a) paired deflectors; b) single deflector; and c) rubble mat. Depth-velocity profiles were generated for each site showing the interaction of the structures with the flow.

a) Paired Deflectors

At the inlet to the structure, the channel flows over a uniform stretch with an average 1.02m water depth and a steady velocity of 0.13m/s (Figure 3.11). At the midpoint of the paired deflectors, the water velocity speeds up to 0.4m/s through the narrowing (3m) of the structures. The depth of water through the paired deflectors reduces to almost half the depth at inlet (average of 0.49m).

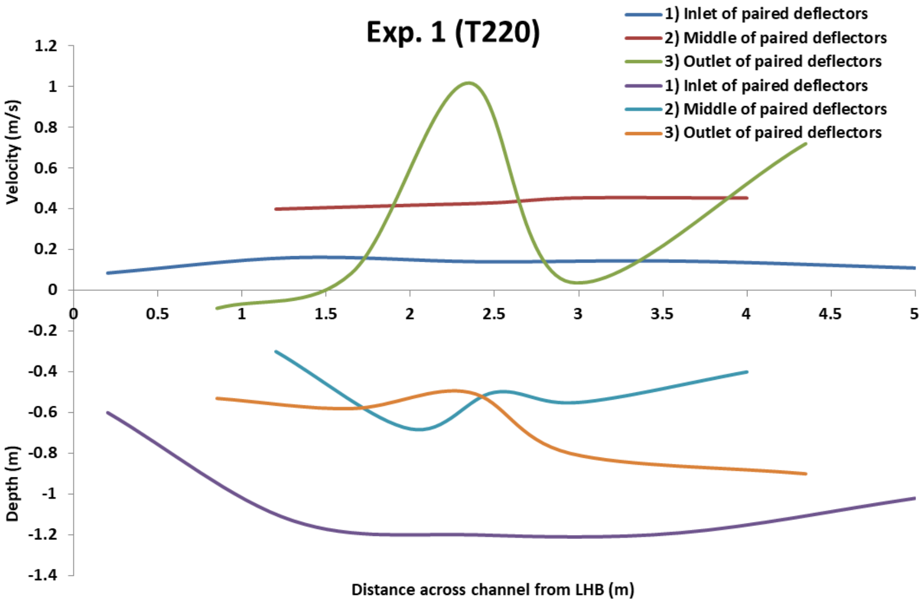


Figure 3.11 Depth velocity profile of paired deflectors located at T220 in Experimental site 1.

Figure 3.12 Photo looking d/s at paired deflectors.

At the outlet or exit of the structure, velocity in the middle of the outlet peaks at 1m/s, and the river scours deeper sections of the channel as a result (Figure 3.11). The graph shows an increase of depths at the outlet compared to mid deflectors.

b) Single Deflectors

This site was located on the left-hand side of the channel. The deflector is 1.5 - 2m in width, which is evident from Figure 3.13. Like the previous example, the installation of this deflector has affected local channel flows. The velocities speed up at the mid-point and outlet in comparison with the inlet. This section of channel has a higher gradient than that of the previous single deflector example (T120 in Exp.1; Figure 3.10). A channel with a greater gradient will naturally have greater velocities compared to a channel with lower gradient, which would explain why there is more variability in flow in this example.

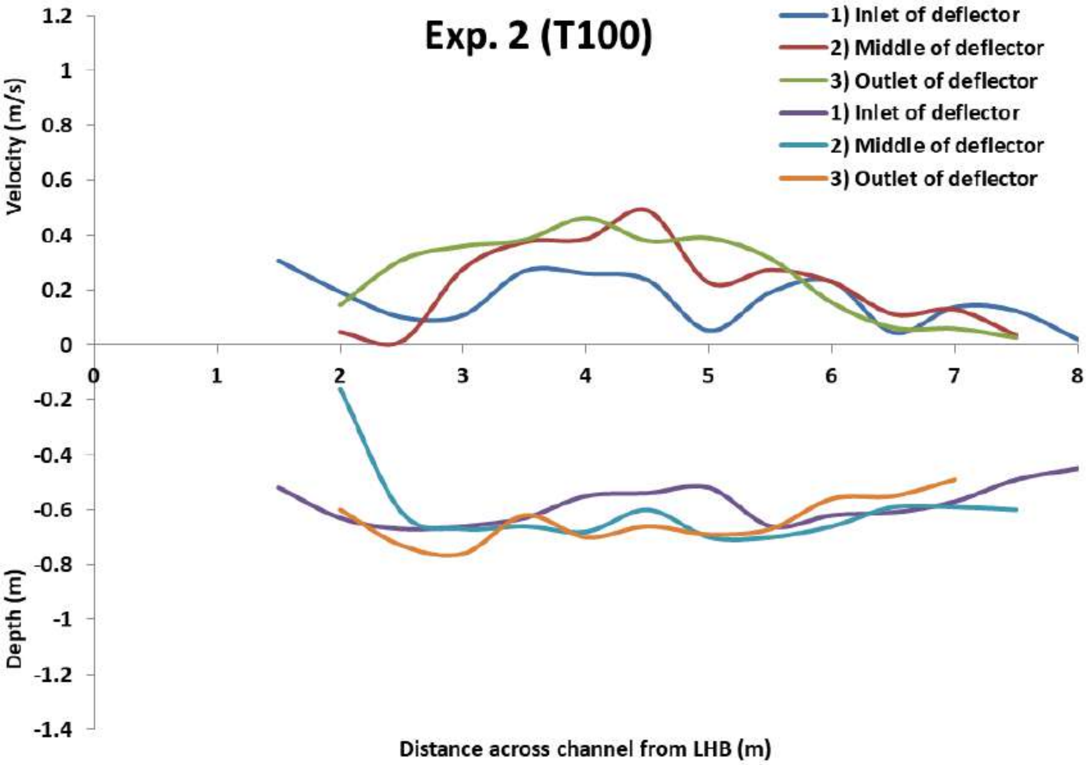


Figure 3.13 Depth velocity profile of a single deflector located at T100 in experimental site 2.

c) Rubble Mat

This structure is designed to create permanent shallows and it is 15m in length, from upstream to downstream. Velocity and water depths were recorded at the inlet, mid and outlet of the rubble mat, and then a depth-velocity profile was generated (Figure 3.14).

Velocities at the inlet and outlet of structure were similar while velocities over the midpoint of the structure increased greatly, peaking at 0.77m/s mid channel (Figure 3.14). The river is slower at the edges of the river channel due to friction with the banks (average velocity 0.11m/s). The depth profile shows the extent of shallowing caused by the rubble mat, reducing depths from an average of 0.72m at the inlet to 0.33m through the structure. The shallowness of the rubble mat is evident in the photo (Figure 3.15).

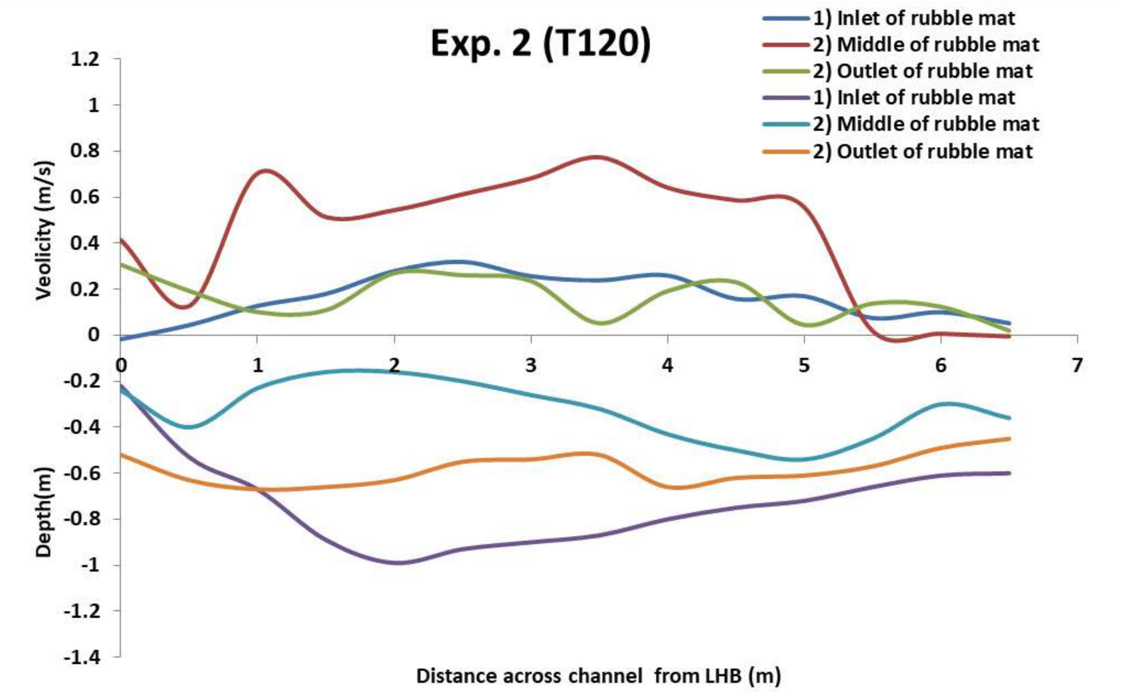


Figure 3.14 Depth-velocity profile of a rubble mat located at transect T120 in Experimental site 2.

Figure 3.15 Photo looking downstream at rubble mat located at T120 in Experimental site 2.

3.3.5 Fish Community

From the first survey in 2009 up to 2019 the river contains a fish community dominated by 1+ and older brown trout and salmon (Figure 3.16 &Figure 3.17). Capturing a range of classes within this riverine system indicates that there is recruitment each year for both species. In 2010, fish numbers captured increased for both experimental sites. In 2019, there is an evident shift in the age classes of fish utilising each experimental site (Figure 3.16).

Brown Trout

Control Site:

2009 and 2010 show similar trends, showing two modal peaks or age classes, whereas 2019 showed a population with, essentially, a single size or age grouping peaking at 18-20cm (Figure 3.16). This Control site was moved a short distance upstream in 2019 as the original control site was rendered unfishable due to debris blocking the channel as well as fallen trees.

Experimental Site 1:

2009 and 2010 display similar trends to the Control site, with 2 clear modal peaks at 1+ and 2+ fish with potentially another developing at 3+. In 2009, prior to Capital Works, the 2+ modal group was larger than the 1+ group. This pattern was altered in 2010, after the installation of the Capital Works, the shift to younger sizes being commonly observed initially following works in a channel. In 2019, there is an obvious shift in age classes to 2+ fish and older fish with very few younger fish of 1+ age recorded (Figure 3.16).

Experimental Site 2:

2009 and 2010 show the same range of brown trout sizes and modal peaks. The shift in modal dominance, in 2010, to the 1+ age group mirrored the situation in Exp.1, following the Capital Works. In 2019 there is a shift in age profile residing in the site with fewer 1+ trout and a greater number of 2+ and of older trout present (Figure 3.16).

Salmon

All three sites supported 1+ salmon in 2009 and 2010. Few fish were recorded in the Control site in any year and salmon were absent from the new control site used in 2019 (Figure 3.17). The Exp.2 site carried the largest numbers of 1+ salmon in all years.

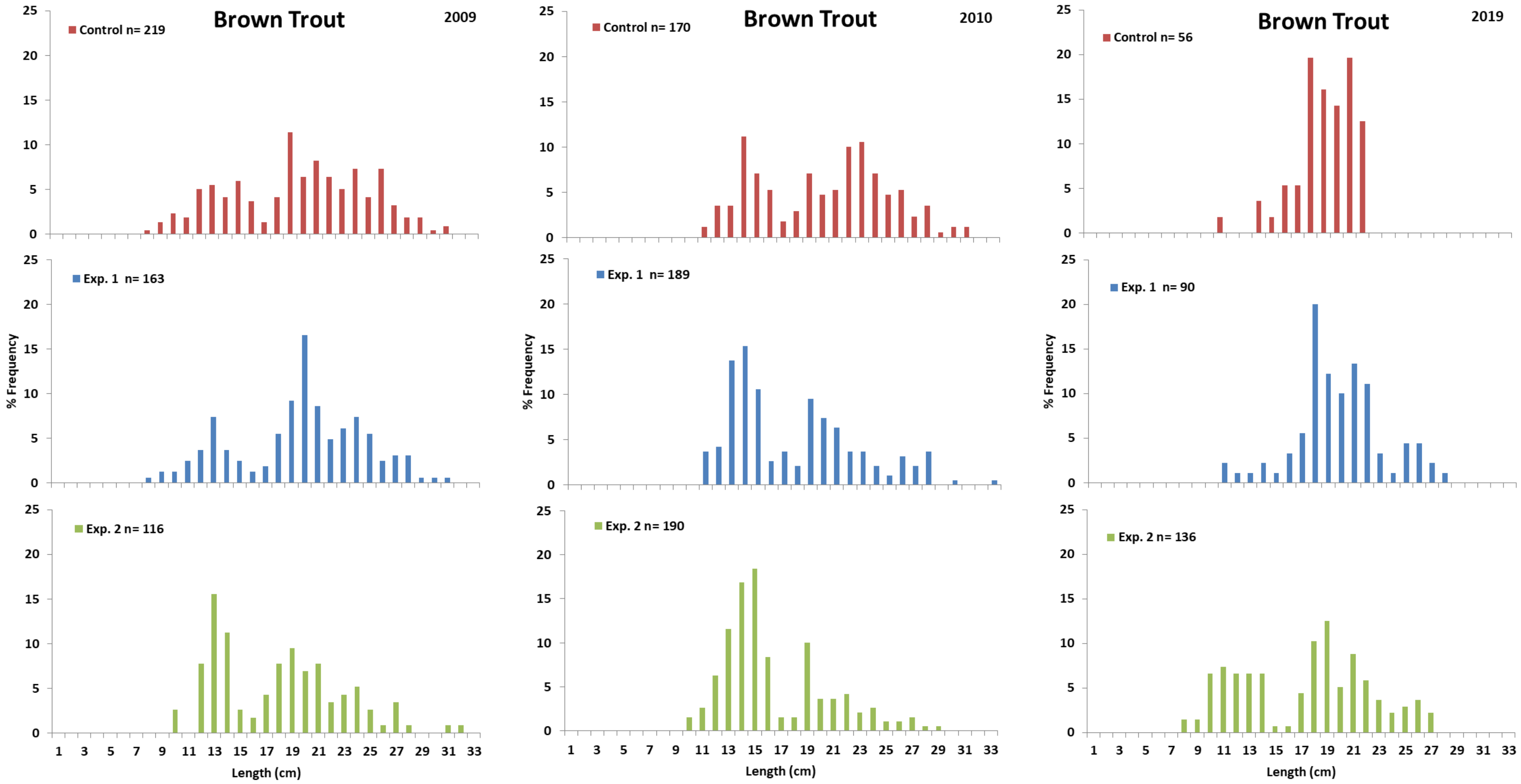


Figure 3.16 Percentage length frequency for brown trout at each site for each year of the survey (2009, 2010, 2019)

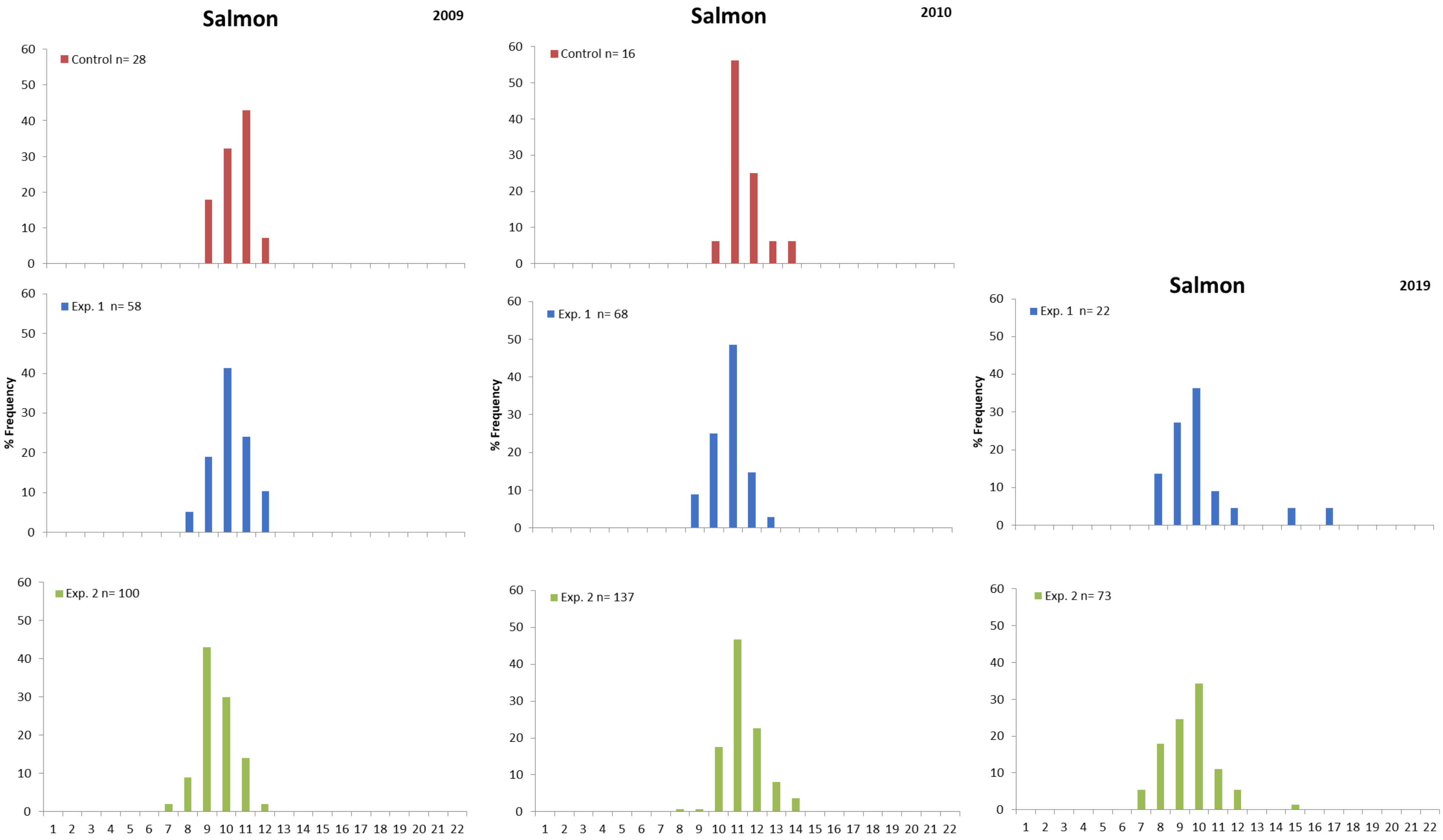


Figure 3.17 Percentage length frequency for salmon at each site for each year of the survey (2009, 2010, 2019). No salmon were caught at the control site in 2019.

3.3.6 Fish Densities

Brown Trout

Brown trout densities for both 1+ and 2+ fish differed between sites. The trends observed in the population structure (Figure 3.16) can be represented in density graphs (Figure 3.18). There were fewer trout caught in the Control site in each successive year of the survey and this is reflected in both the 1+ and 2+ age class densities. The site supported both age classes, with relatively higher densities of 2+ fish in each survey year and this may be a reflection of the relatively deep habitat predominating here. The Exp.1 supported both age classes across all survey years. There was an increase in the density of 1+ trout between 2009 and 2010, possibly a reflection of initial site disturbance due to Capital Works. This decreased in the 2019 survey, with a notably low density of this age group. There was a higher proportion of 2+ brown trout captured in all years at this site, relative to 1+ trout and, like the Control site, this may be a reflection of the overall water depth. The Exp.2 supported both age classes of trout over all survey years. There was a consistent population of 1+ and 2+ trout between 2009 and 2010 but a sharp reduction in density of 1+ trout was noted in the 2019 survey. The density of 2+ and older trout increased here in 2019.

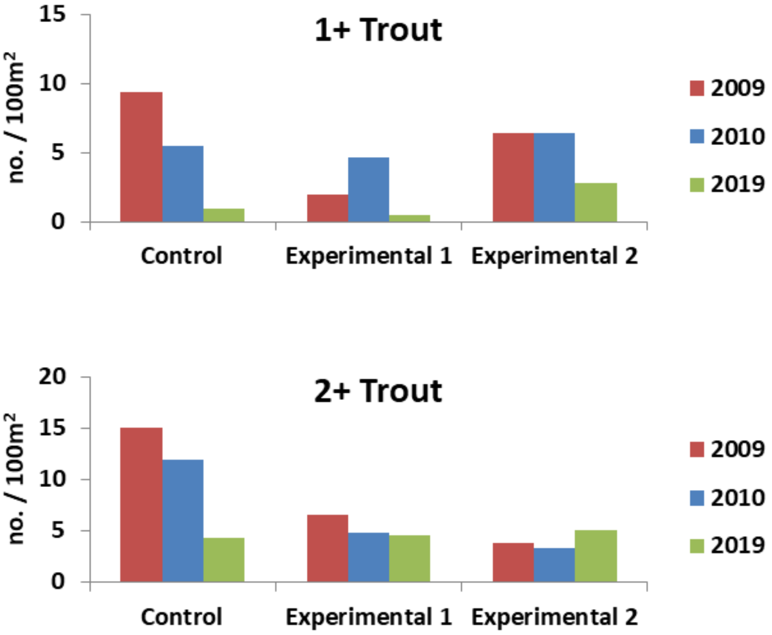


Figure 3.18 Population density (no./100m^2) of brown trout at all of the Enfield Blackwater survey sites (Control, Experimental site 1 & Experimental site 2).

Salmon

Salmon densities in the Exp.1 showed little difference in density over the three years of survey and were comparable to the density values recorded in the Control site (Figure 3.19). The Exp.2 showed a slight decrease each year of the survey (Figure 3.19). The density of 1+ salmon was substantially higher in Exp.2, relative to the other sites in all years. This is considered likely to be linked to the higher bed gradient and shallower water at this site. It was envisaged that the experimental works here, in adjusting the instream hydromorphology, would also create increased habitat area and holding ground for 1+ salmon. This was not apparent from the 2019 data but it is important to stress that such monitoring should be undertaken at greater frequency to detect the range of natural shifts and changes in these biological variables.

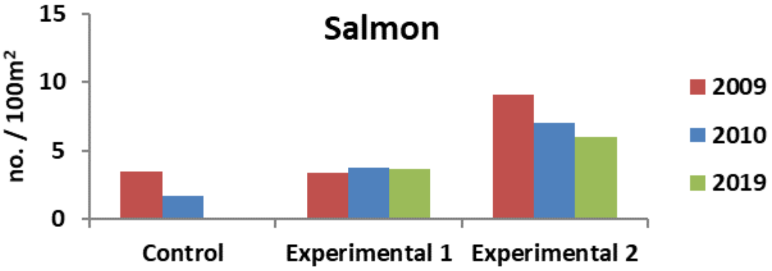


Figure 3.19 Population density (no. /100m^2) of Salmon at all of the Enfield Blackwater survey sites (Control, Experimental site 1 & Experimental site 2)

3.4 Conclusion

When compared with 2019, the longitudinal profile post-Capital Works in 2010 has remained largely intact for both experimental sites. The three paired deflector/pool complexes at Experimental site 1 (Exp.1) have remained intact, with one slightly infilling. The two spawning gravel shoal/pool complexes at Experimental site 2 (Exp.2) are also intact. When implemented in the correct setting, Capital Works measures can become long-term features within the river channel. These outcomes are supported in the width-depth heat map at Exp.2, where the rubble mat has maintained the shallow stretch of channel. Such habitat would be positive for supporting juvenile fish populations and spawning for older fish. The heat mat at this site also shows the thalweg introduced as part of the Capital Works has migrated within the confines of the channel. This is a positive result as natural riverine process of lateral movement has re-established even in an artificially confined corridor, showing it is a dynamic environment.

The cross-sections presented show the Enfield Blackwater river corridor had quite high banks from the original arterial drainage scheme and some berm formation within the river corridor.

It could be seen that one of the installed deflectors had been incorporated into the cross-sectional area, with marginal vegetation established and some variation in flows present.

The depth-velocity profiles at both experimental sites show a number of structures implemented as part of the Capital Works programme. When the river flow encounters the paired and single deflectors the depth is altered and the velocities speed up. The rubble mat has maintained a shallow fast-flowing section over a 15m stretch of channel. All of the examples highlight how Capital Works structures have locally altered the flow types and channel form, important components of hydromorphology within the river corridor.

The control site showed a decrease in fish densities for both brown trout and salmon over time. The site supported both age classes of brown trout with relatively higher densities of older trout in 2019. Both of the experimental sites supported both age classes of brown trout across all survey years. Exp.1 showed an increase in the density younger trout between 2009 and 2010, after the Capital Works. However that trend reversed in 2019 with mostly older trout captured. Both sites showed a relative decrease in 1+ brown trout densities in 2019, with 2+ trout densities remaining consistent. Salmon densities remained largely consistent over the survey years at all sites, with numbers of fish caught decreasing in 2019. Brown trout densities (1+ and 2+) were compared statistically between the control and each experimental site for all survey years and there were no significant differences found.

The Capital Works plans implemented at these sites have largely stayed intact. Their effect on the river has been to create more diversity in flow types and channel form, providing some good habitat for riverine fauna within an artificially confined channel. The impacts of the structures on overall channel depth – velocity relations are quite localised. There is evidence in the fish community present that a variety of age classes are supported at these sites, with pools providing suitable refuge habitat for older fish and the shallows providing suitable juvenile or spawning habitat. There was no evidence that the positive hydromorphology impacts were reflected in any increased production of brown trout or of salmon. From a hydromorphology perspective, there is some evidence of re-naturalising of the main flow of the river within the confines of the river banks which could promote self-sustaining habitat.

4 Long-term study II: Eignagh (Enhanced Maintenance)

4.1 Background

The Eignagh River (OPW channel reference C1/49) is a fourth order tributary of the River Moy in Mayo. The river flows south-east from Lough Talt, through Aclare, then drains a bog area before entering the main Moy River. This river, although relatively small, plays an important role for diadromous fish species, with Atlantic salmon using it for spawning as the riverbed supports good spawning gravels in its upper reaches. Individual adult sea lamprey have also been found here in the 2006 and 2007 surveys. The main stem of the channel is 12.7km in length, with survey sites located within a 2.4km stretch (Figure 4.1).

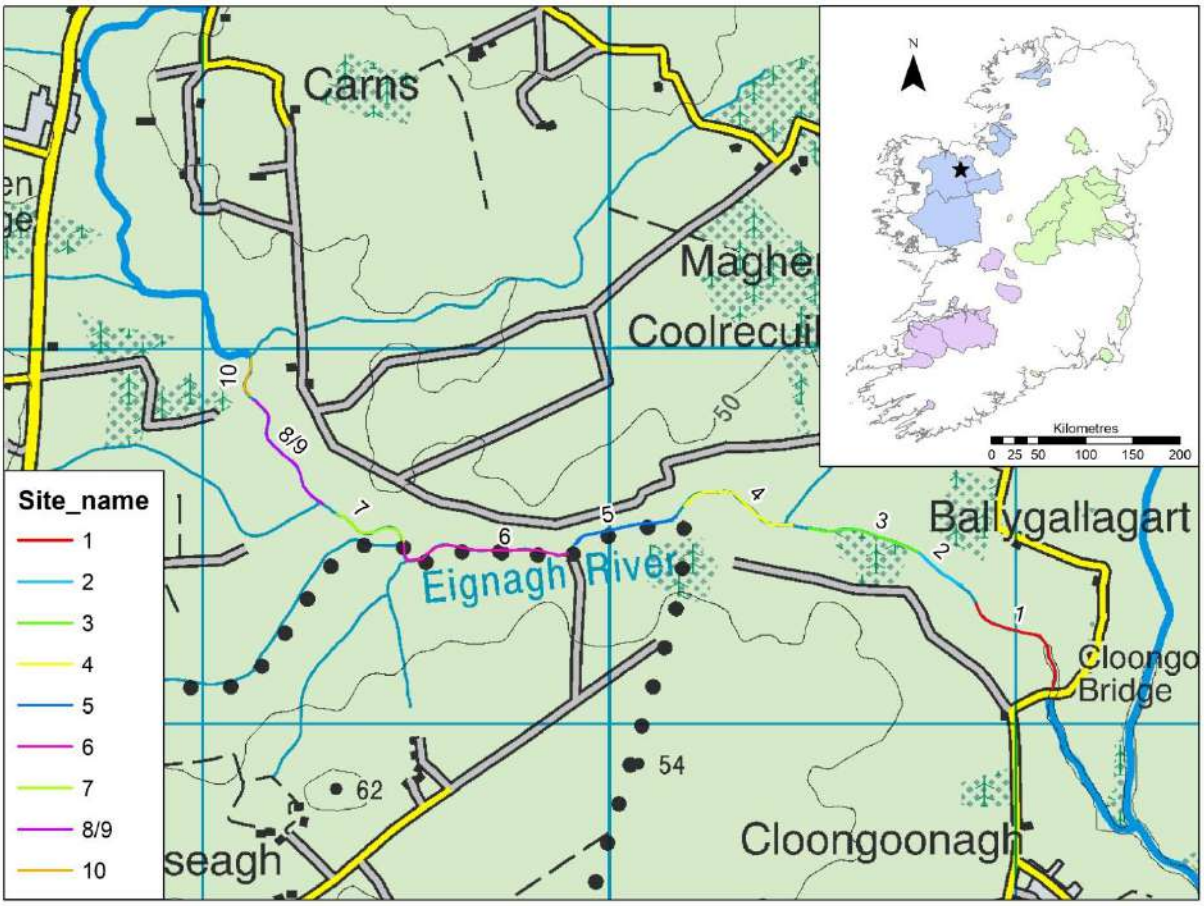


Figure 4.1 Locations of the study sites along the Eignagh (INSET: Location of the river in the Moy catchment in the OPW west region).

The river is part of the OPW's Moy Drainage Scheme. This channel was listed for maintenance in 2005 and discussion between the OPW's Ballina office and IFI (then Central Fisheries Board) in the context of the Environmental Drainage Maintenance (EDM) project, the precursor of the EREP, identified the suitability of the channel for monitoring and assessment of the proposed maintenance work and to assess the implementation of enhanced maintenance options, as per the OPW's environmental guidance, introduced in 2003. The maintenance work envisaged significant management and removal of tree cover primarily alder and willow, as well as substantial re-profiling of bank slope areas. This latter action was likely to impact on the wetted channel. However, there was no programme of substantial de-silting of the instream channel or wetted area. A series of 10 locations were selected in a relatively low gradient part of the channel, extending from downstream of Aclare to Cloongoonagh Bridge to investigate the impact of intensive tree removal on fish populations (Figure 4.1). The river was subject to maintenance in autumn-winter 2005 and the fish and habitat surveys of IFI were undertaken in 2005, prior to maintenance, and in 2006 and 2007 to assess post-maintenance impacts. Long-term monitoring was undertaken in 2014 under the EREP project and a further round of assessment was completed in 2019. This latter survey was in the context of additional proposed small-scale use of tree material by OPW to create low-level instream structures as an experiment within EREP.

4.2 Survey

4.2.1 Fishing

The river was electro-fished using a boat method in each survey year. The fishing was initially a mark-recapture fish surveying method, although this was modified in 2019 when the sites were fished using a float-over single-pass fishing. In 2019 the fish captured were counted, measured and returned to the channel. The target species for quantitative examination were brown trout and Atlantic salmon. Note was made of other species present and a representative sample was captured and measured.

4.2.2 Physical Measurements

The channel’s physical attributes (depth, width) and canopy cover were recorded in transects at 5 metre intervals in each of the study sites from 2005 onwards. Depth was measured at 7 points across each transect – two at the wetted edges, and the remaining 5 equally spaced across each transect with one taken at the midpoint. Canopy cover was measured using a spherical densiometer at four points across the channel, one at each edge facing the bank and two in mid channel – one facing upstream and one facing downstream.

4.3 Results

4.3.1 Fish community

Over all of the survey years, species encountered were brown trout, salmon, minnow, perch, roach, sea trout, stoneloach, and three-spined stickleback. From the first survey in 2005 up to 2019 the river's fish community was dominated by brown trout (Figure 4.2). The percentage length frequencies for brown trout remained very consistent over all years. A range of size/age groups of trout was present, with a modal peak in the 10 – 13cm range representing 1+ brown trout (Figure 4.2). The range of larger trout represented 2+ and some 3+ fish.

The percentage salmon length frequency showed some variation over the study period (Figure 4.2). The population of salmon was composed of 1+ fish in all years. The fluctuations in number would be considered more likely in the case of salmon than of trout, the salmon being a migratory fish and spawning success being dependent on marine survival of young fish gone to sea and of the adult salmon returning. The brown trout are resident in the river and would not experience the same pressures.

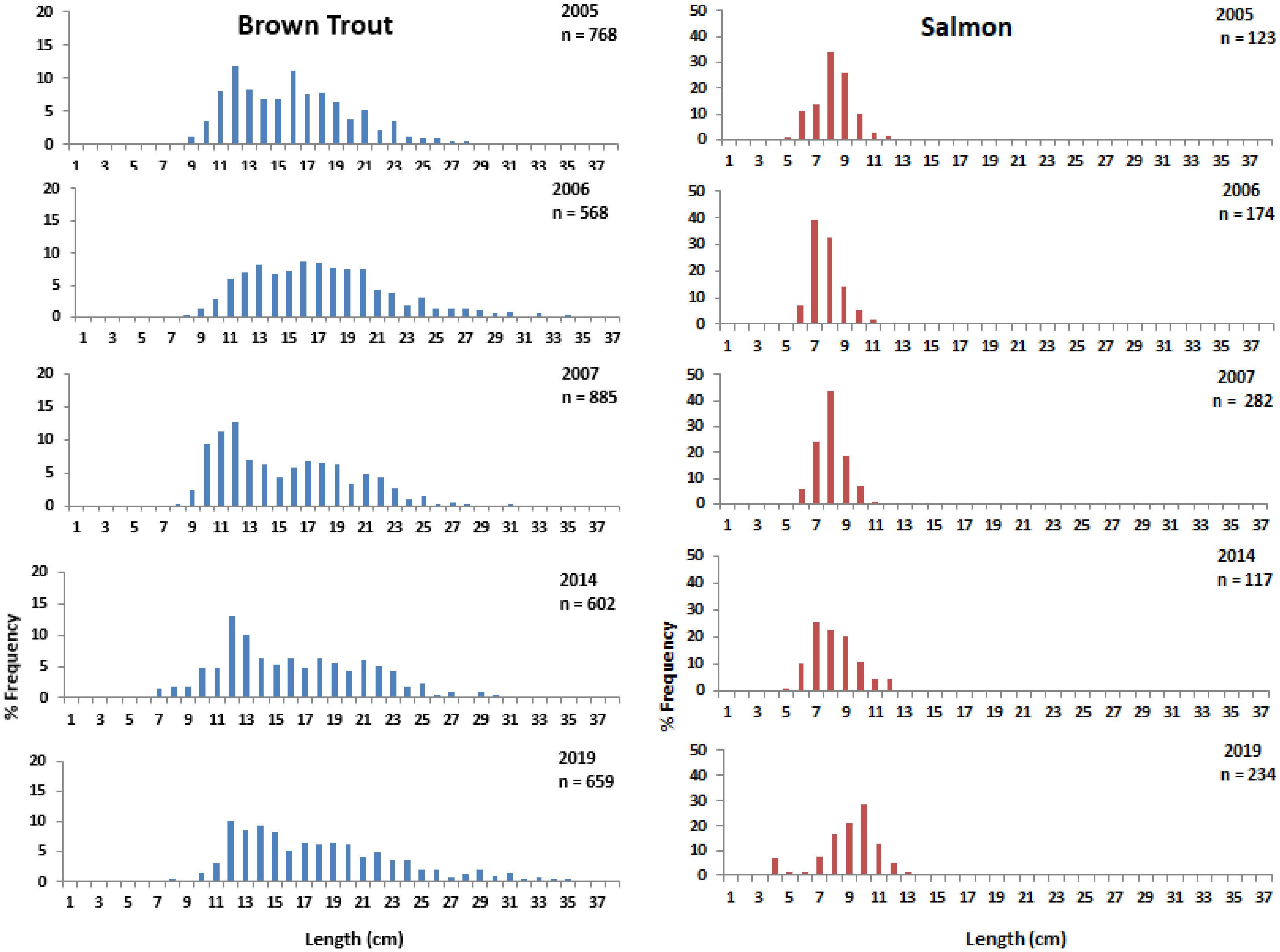


Figure 4.2 Percentage length frequency distribution of all brown trout (left) and salmon (right) captured in all ten sites for each survey year.

4.3.2 Fish densities

Fish densities were calculated for both trout and salmon at each site, determining fish numbers per 100m^2 (Figure 4.3). Within all sites there was inter-annual variability in fish densities. In this regard, the control site (site 2), where no tree cover was present and no tree management was required in 2005, showed similar trends in brown trout density to sites 3 and 4. Some individual sites had more consistent densities between years, for example sites 1 and 6.

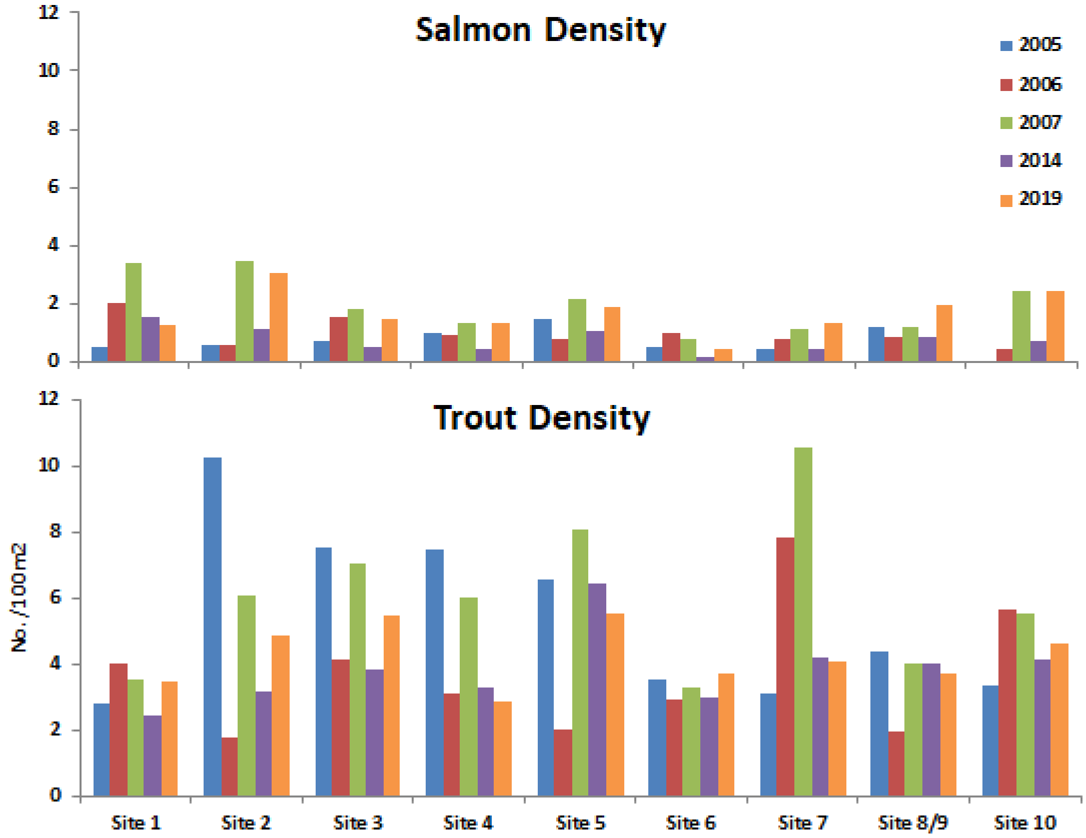
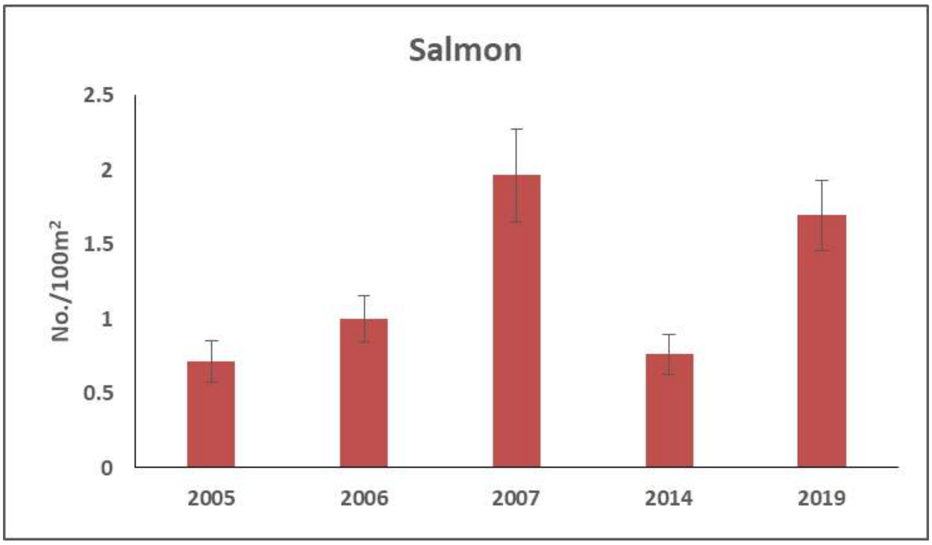


Figure 4.3 Density of Salmon and Brown Trout per 100m^2 for each site fished in each survey year.

The overall mean densities for salmon and trout also show some variation (Figure 4.4). The salmon densities increase after the maintenace, in both 2006 and 2007. By 2014, there is a marked decrease, which recovers to 2007 levels in the 2019 survey. The mean brown trout density shows a decrease following the initial maintenance. In 2007, like the mean salmon density, there is an increase. Similarly in 2014 there is a marked decrease, which recovers slightly in the 2019 survey.



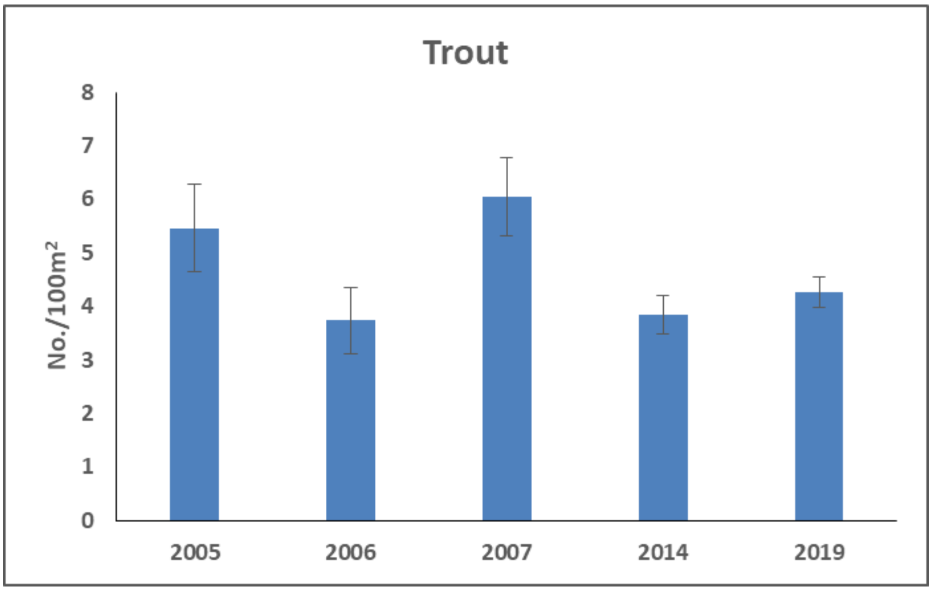


Figure 4.4 Mean density of salmon (top) and brown trout (bottom) for each year (2005, 2006, 2007, 2014 & 2019) with standard error.

Mean densities were compared across all sites, for salmon and trout separately, between years using an unpaired t-test assuming unequal variances ($p < 0.05$). Between 2005 and 2006 the difference in the means for salmon and trout densities was not significant. For the 2006/07 and 2007/14 tests, the difference in the mean densities for both species was found to be significant (see Figure 4.4). For the years 2014/19 the difference in mean salmon density was significant, but brown trout was not.

4.3.3 Canopy cover

Channel maintenance, which consisted primarily of tree management, was completed on the Eignagh in the winter 2005 - 06 period. Tree management works consisted of removal and trimming (Figure 4.5).

Figure 4.5 Photos upstream of Cloongoonagh Bridge pre works (left) in 2004 and one year post works (right) 2006.

Tree management works completed in winter 2005-06 reduced the percentage of canopy cover recorded in 2006 to less than half of what was recorded before maintenance commenced. Sites 1 & 3 were excluded from the physical surveys in all years of the survey as tree management had already been completed at these sites. Site 2 acted as a control from 2005-2007 as this site had little tree coverage and remained untouched for the 3 year period (Figure 4.6). Site 4 did show a reduction in percentage canopy cover between surveys in 2006 and 2007. Factors other than maintenance, which influence canopy cover in these sites include the natural cycle of trees, particularly alder trees, and this may have impacted this result in site 4. Trees dying off and falling into the channel or lying on the bank slope reduce measured canopy cover. The fallen tree is then not providing any cover for the water body, but now has the ability to create habitat within the riverine corridor and this may have occurred in Site 4 between 2006 and 2007.

Annual mean percentage canopy cover recorded for the section of channel surveyed physically was 19% in 2006 and 17% in 2007, showing there was little difference in tree growth over the two years (Figure 4.7). Canopy cover recorded in 2014 showed a substantial amount of tree growth over the seven year period since 2007 amongst all sites with an average of 45% canopy cover for the entire stretch (Figure 4.7). A noticeable decrease was evident in percentage canopy cover between 2014 and 2019. This was due to a subsequent round of tree management undertaken in maintenance by OPW.

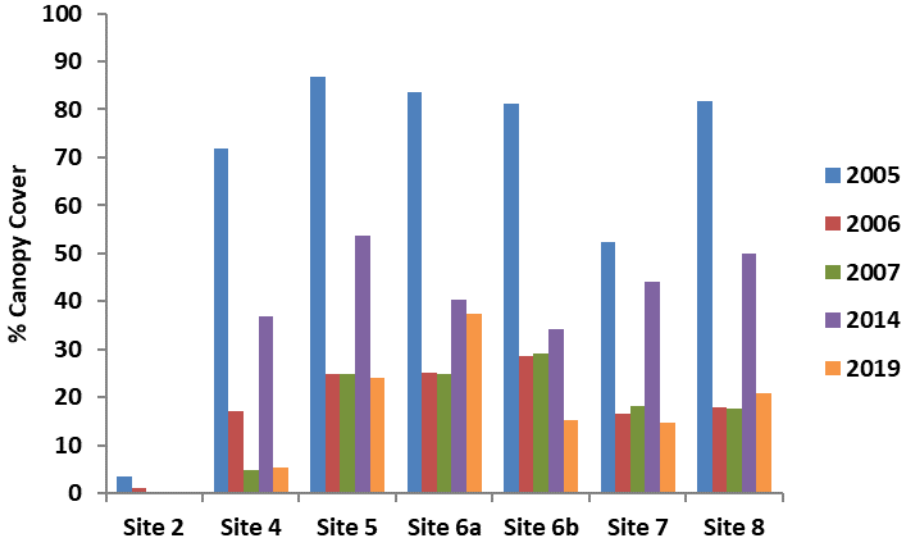


Figure 4.6 Percentage canopy cover for sites on the Eignagh River 2005 to 2019.

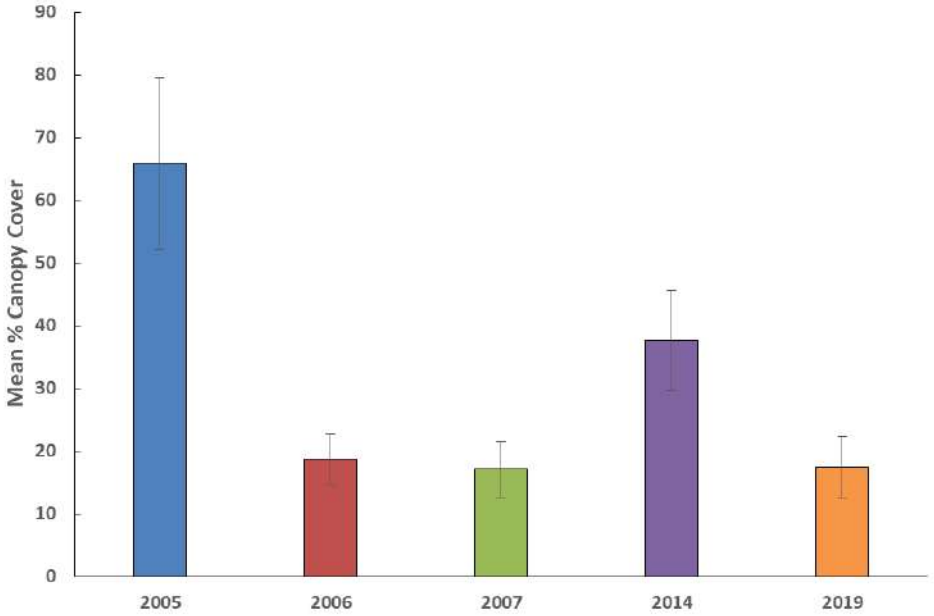


Figure 4.7 Annual mean percentage canopy cover of entire stretch of channel surveyed each year with standard error.

An unpaired t-test assuming unequal variance was carried out on the mean percentage canopy cover across all sites in the Eignagh. There was a significant difference in the mean percentage canopy cover between all consecutive survey years except 2006/07 when the canopy cover remained consistent (see Figure 4.7). The sequence of monitoring summarised in Figure 4.7 shows a series of substantial changes in tree canopy cover with the reduced cover levels of 2006 and 2019 linked to OPW maintenance events on the channel.

4.3.4 Water depths

Water depth is quite variable at any site in any survey and will fluctuate with flow levels in a river. As such, depth is not constant from year to year. Channel maintenance undertaken by OPW in the Eignagh, completed in 2005, was solely focused on tree management and on local bank slope realignment. There was no instream maintenance involving desilting or other factors that would widen the channel.

The same procedure was undertaken in each survey when recording water depth at sites. The depth data was sorted to identify the level of water depth greater than 0.45m at each survey site. This was a working cut-off depth value used in brown trout studies in the USA to establish the extent of 'deeper' water available to brown trout (Wesche *et al*., 1987). In 2006 (post-maintenance) there was an increase in depths greater than 0.44m compared to 2005 (Figure 4.8), most notably in Sites 5 and 9. The proportion of channel depth exceeding the 0.45m cut-off continued to increase in most sites through the 2007 and 2014 surveys. However, levels generally showed a decrease in the 2019 survey (Figure 4.8).

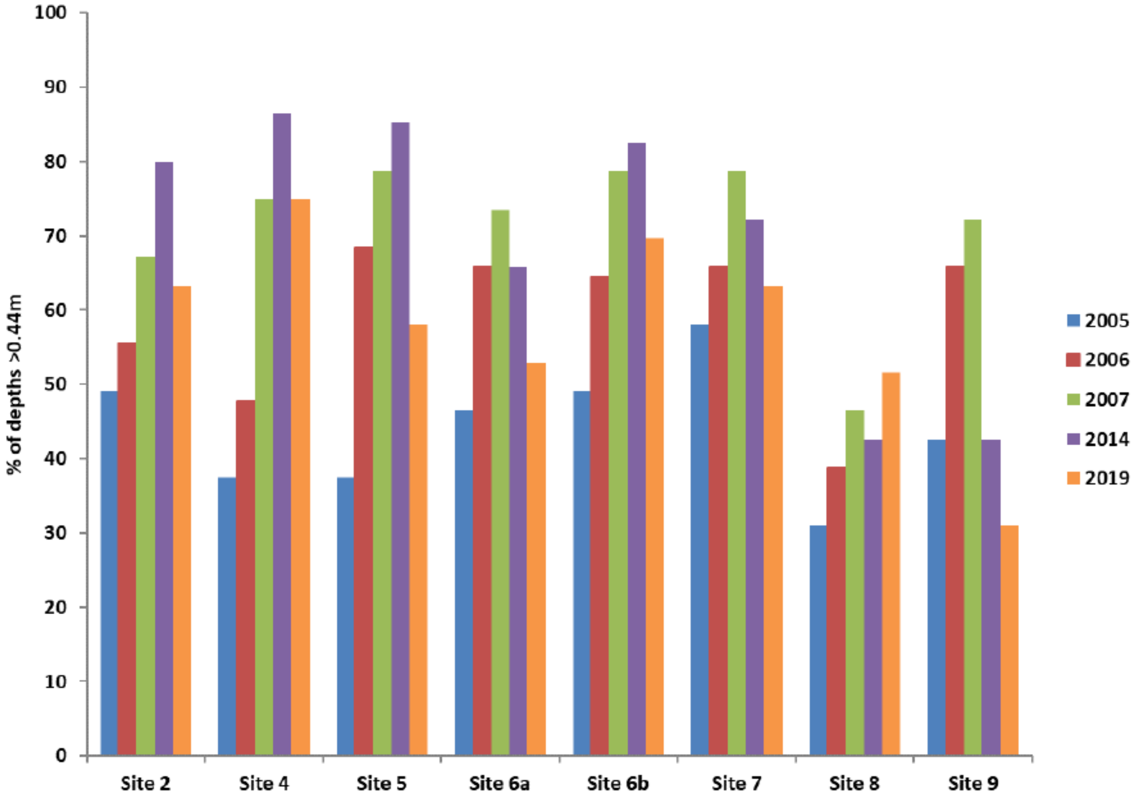


Figure 4.8 Percentage of depths >0.44m recorded at each site each year of the survey.

The mean annual percentage of depths >0.44m also show changes from year to year. As the maintenance at these sites was not concentrated on instream works, it is likely that variation in water depths relates to antecedent weather conditions prior to the survey.

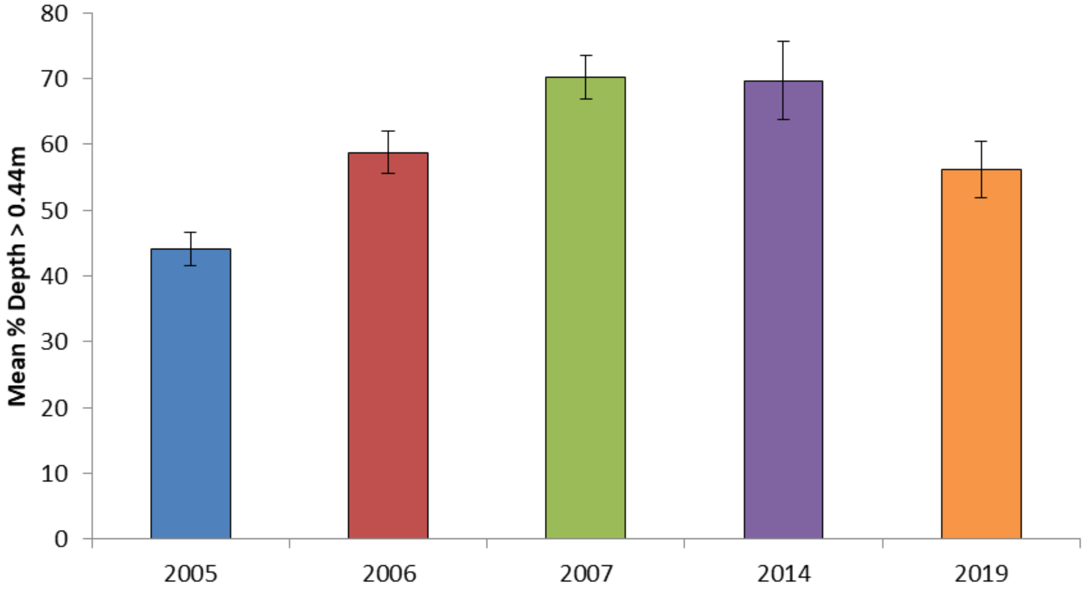


Figure 4.9 Mean percentage depths >0.44m over the entire stretch of channel surveyed in each year with standard error.

An unpaired t-test assuming unequal variances was undertaken for the % water depths >0.44m. There were significant differences found between 2005/06 but not for the other survey years (see Figure 4.9).

4.3.5 Population densities vs physical attributes

Scatter plots were used for an initial assessment of any linkages between the fish densities with both percentage canopy cover and the percentage depths >0.44m. This was done for both brown trout and for salmon data. The large number of replicate sites and repeat years, with substantial variation in canopy cover, especially, provided a substantial data set to examine. There were no distinct relationships apparent in respect of either fish species and either variable, with very low R^2 values (Figure 4.10 &Figure 4.11) suggesting canopy cover and water depths have no impact on brown trout densities at this location.

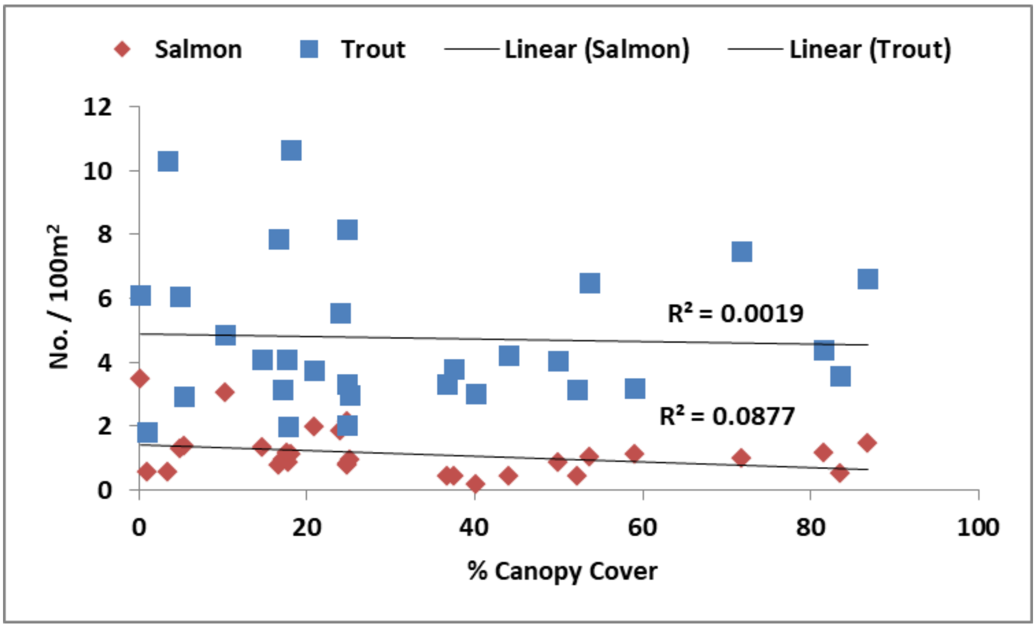


Figure 4.10 Percentage canopy cover vs fish density (numbers per 100m^2) for brown trout and salmon.

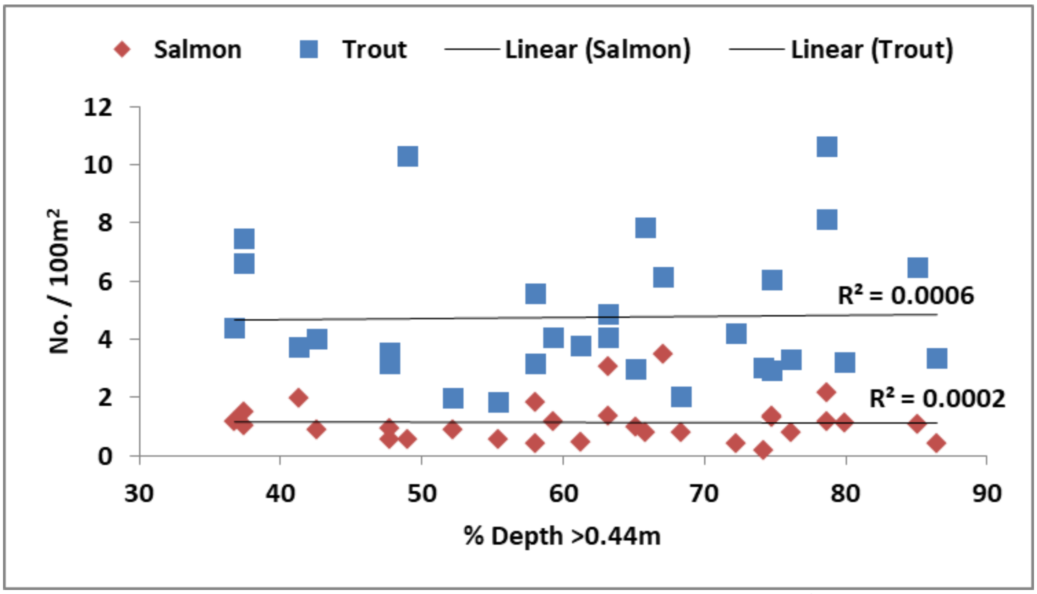


Figure 4.11 Depth >0.44m vs fish density (numbers per 100m^2) for brown trout and salmon.

4.4 Conclusion

Maintenance by the OPW in 2005 had a major impact on canopy cover at all treated sites. Mean percentage canopy was reduced from 65% in 2005 to 18% in 2006 (Figure 4.7) and this difference was significant. The changes in salmon and brown trout populations following maintenance were not statistically significant. There was an increase in mean depths in both years following maintenance, which may be a factor of water levels at the time of the surveys, rather than any treatment effects.

By 2007, the salmon and brown trout numbers were increasing, with the highest mean densities of all surveyed years recorded, a significant difference from 2006 (Figure 4.4). The associated measured increase in mean depths greater than 0.45m likely reflected the presence of more pool areas within the channel which provided suitable fish habitat. At this time, the canopy cover was similar to 2006 levels with no significant change (Figure 4.7).

By 2014, nine years after the initial survey, there was a significant increase in canopy cover (to 45%), but it had still not returned to pre-works level. Depths had increased at some, but not all, of the sites. For both salmon and brown trout, there were lower numbers and mean densities recorded and this difference from the 2007 survey was significant. Anecdotal evidence suggests there may have been antecedent weather conditions (flooding) in the previous weeks which affected the local fish populations.

Maintenance occurred again after the 2014 survey. The decrease in cover after the 2014 survey was significant. By 2019, the canopy cover had not re-established widely, and overall was similar to that measured in 2006/7. There was a decrease in mean depths and an increase in both salmon and brown trout numbers/densities. The change in the trout population was not significant but the change in the salmon population was significant compared to 2014.

The study on the Eignagh shows that tree management has an important role within an OPW maintenance scheme. Both maintenance cycles in 2005 and 2014 had a large and measureable impact on canopy cover. Overall, a consistent brown trout population structure was observed over the study period. No relationship was observed between fish populations and the physical variables examined, which included canopy cover and water depth. Antecedent conditions present a confounding variable which was difficult to assess in this scenario. ‘Tunnelling’ or heavy tree cover reduces primary productivity, and hence reduces brown trout levels. This was not an issue in the Eignagh and indeed there was not much woody debris addition to the channel. Some canopy cover is required to create instream habitat for brown trout. The investigations of Wesche *et al.* (1987) on resident brown trout in Wyoming, USA, identified a series of factors contributing to brown trout cover, including canopy cover, water depth exceeding 0.45m and bed composition, with cobble and gravel providing shelter and hiding places for fish. The long-term study on the Eignagh indicated the presence of a substantial population of brown trout and displayed the capacity of this channel to carry such population in circumstances where the canopy cover levels and water depth showed large fluctuations.

5 Long-term studies: channel maintenance modifications of long-sections and cross-sections

The initial Environmental Drainage Maintenance (EDM) study of OPW and IFI (1990-2007) examined a series of strategies, including excavation or digging options, that could be routinely undertaken by OPW driver crews in the course of channel maintenance and that might have a degree of longevity or permanence. An extended ‘life span’ for such works could provide habitat benefit for resident or migratory fish species, with an emphasis on the life history of brown trout and Atlantic salmon. The digging works were intended to be undertaken within the channel cross-sectional area and might occur either at localised points or on a more extended basis – resulting in a modification of the cross-section locally or modification of the channel longitudinal profile and/or cross-sections. They are summarised in two of the topics covered in the OPW’s 10-point environmental guidance (Brew and Gilligan, 2019):

- Topic 7 – Managing berms
- Topic 10 – Excavation in the channel

The opportunities were built into the Environmental Drainage Maintenance training delivered to OPW staff in 2003 and again in 2009. Specific studies were undertaken in pilot sites and the extended nature of the EDM and the EREP studies has enabled examination of long-term changes or impacts of some of the excavation strategies. A series of these were re-surveyed in the 2017-19 period and are reviewed below.

5.1 Clonshire

5.1.1 Background

The Clonshire River (OPW channel reference C1/17) is small tributary of the Maigue. It is 17km in length, and the survey site is on a third order section, 11.2km downstream from the headwaters (Figure 5.1). The Maigue catchment was arterially drained between 1973-86.

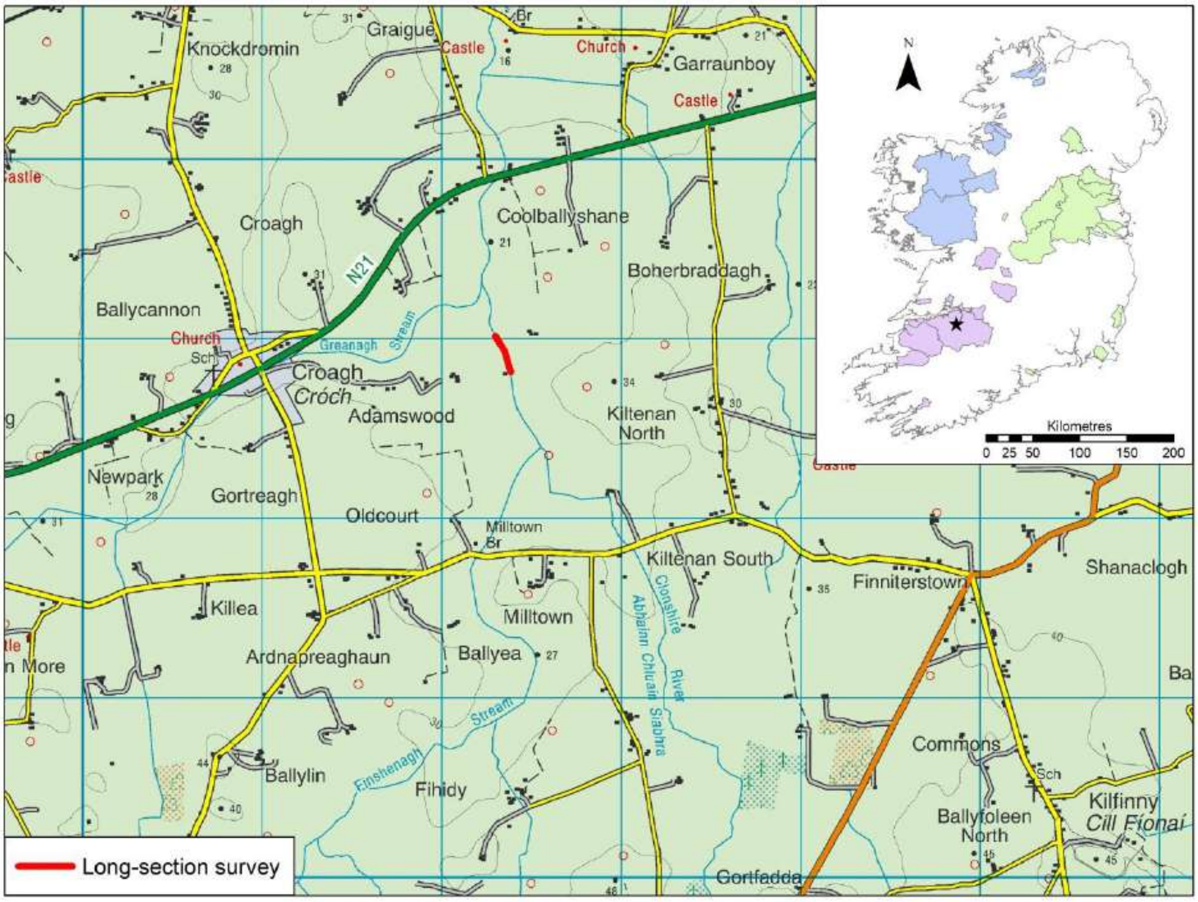


Figure 5.1 Location of the Clonshire River in the Maigue catchment (OPW South-west region, inset). The red line indicates the stretch of river surveyed.

5.1.2 Survey

In March 2007, a walkover survey was undertaken on this channel with OPW staff to assess the potential for implementing enhanced maintenance opportunities. This initial survey identified several sections of uniform glide that would benefit greatly from the excavation of the channel bed to create strategically placed deeper pool areas and adjoining shallow riffles. A pre-works levelling survey of the longitudinal section and 7 representative cross-sections was conducted in August 2007 immediately prior to the experimental diggings by the OPW driver team and this was repeated the following day on completion of the agreed digging work. The pools were dug at a distance of approximately 50-60m apart, with the distance between each pool relative to channel width.

The enhancement works consisted of a total of 5 pools being excavated within a 200m stretch of channel. Pools were dug where tree cover would shade the channel and be beneficial to fish utilising the pools. The material excavated was placed in the channel directly downstream of the pools to create riffle habitat (Figure 5.2).

Figure 5.2 The Clonshire study site showing the pre-digging situation (left) and changes following bed excavation and formation of pool and riffle (right).

The experimental site was re-visited in 2019 by OPW and EREP team and a re-survey of the long-section and cross-sections was undertaken.

5.1.3 Results

Longitudinal profile:

The blue line is the bed level that remained since the original drainage scheme displaying a uniform glide overlying a largely uniform bed gradient (Figure 5.3). The red line represents the bed levels achieved after the works were completed in 2007 and it is evident how the longitudinal profile was altered. The strategically placed pools and riffles were very obvious in the channel bed level. During the re-survey in 2019, it was evident that the pools remained and the riffle effect was still there 13 years later. The small displacement in the graphic is due to operator 'error' and absence of an absolute bench mark for levelling.

The pools were dug to approximately ~0.6m depth during the works. It is evident from the long section that these pools have filled in to varying degrees. This is due to the natural process of deposition within the channel (Figure 5.3, Table 5.1). Apart from the one pool that appeared largely filled in, the average degree of 'filling' of the excavated pools was 50%. On average, this provided an additional element of 0.3m depth below the design bed level or below the approximately 0.4m water depth compared to un-excavated sections of channel i.e. pool areas of approximately 0.7m remained to provide habitat and 'cover' for larger-sized brown trout or for adult Atlantic salmon migrating upstream. The water surface level indicates the noticeable change in gradient at riffle areas.

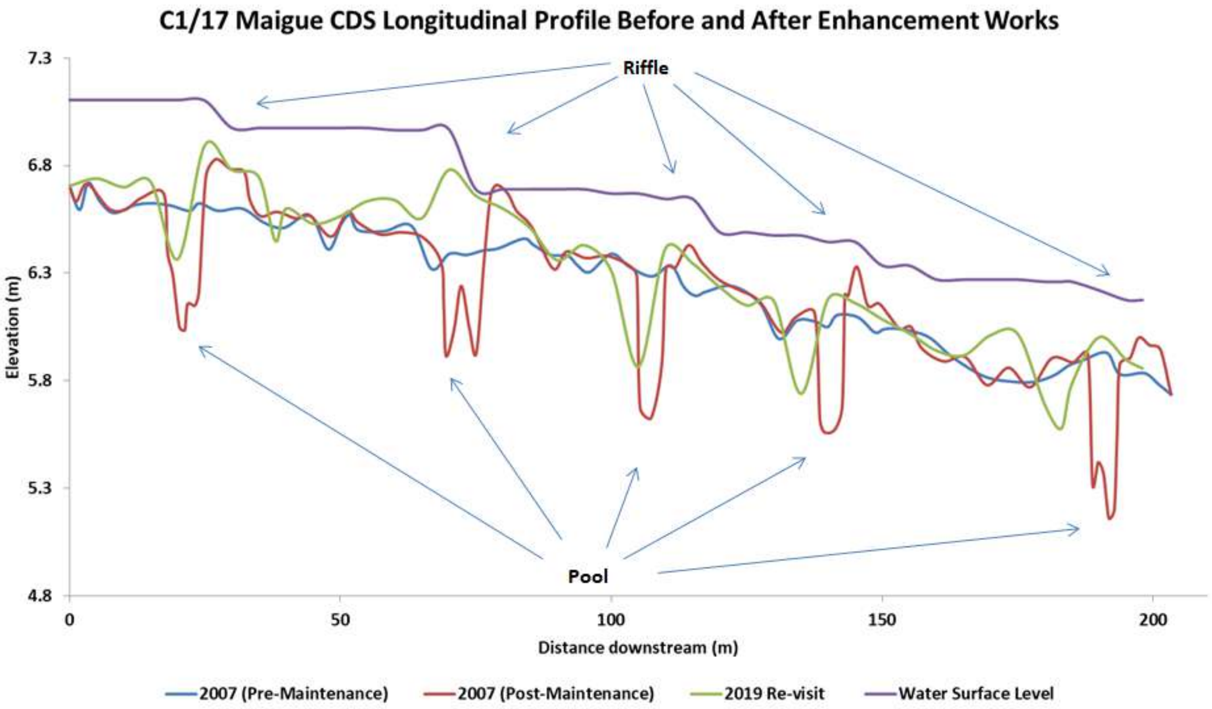
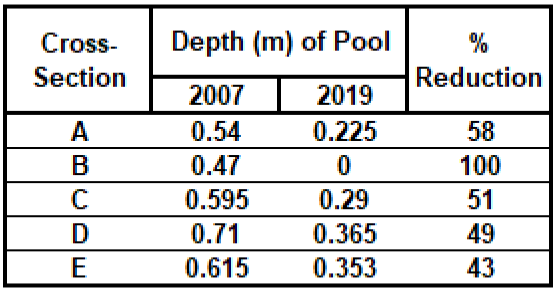


Figure 5.3 Longitudinal profile of the 200m stretch of channel in the Clonshire River, where enhancement works took place in 2007. Pools from upstream to downstream are coded A-E.

Table 5.1 Depth of the pools in 2007 directly after works compared with pool depths in 2019 indicating infilling in the time between surveys.



Cross-Section	Depth (m) of Pool		% Reduction
	2007	2019	
A	0.54	0.225	58
B	0.47	0	100
C	0.595	0.29	51
D	0.71	0.365	49
E	0.615	0.353	43

Cross-sections:

Profiles were repeated at two of the seven original cross-sections surveyed in 2007 (Figure 5.4). Over the 13 years since the initial study, tree growth had been significant on the working bank posing difficulties when repeating these cross-sections. The tree growth hindered visibility therefore it was impossible to undertake the surveys at every location. The blue lines (pre-works survey) display a typical uniform trapezoidal cross-section (Figure 5.4) evident in most OPW channels within the catchment-wide drainage schemes. The form suggests little or no change due to any natural river processes since the drainage scheme was completed. The red line (post works) shows the excavation of pool areas of 0.5 – 0.7m depth in the centre of the channel. Over time the pools have shifted across the channel indicating lateral river processes are on-going within the confined banks (green line). The altered shape of the cross-section due to the experimental digging would have focussed stream power of the river during different flow events causing a small degree of scouring of the channel bed and movement of sediment or substrate.

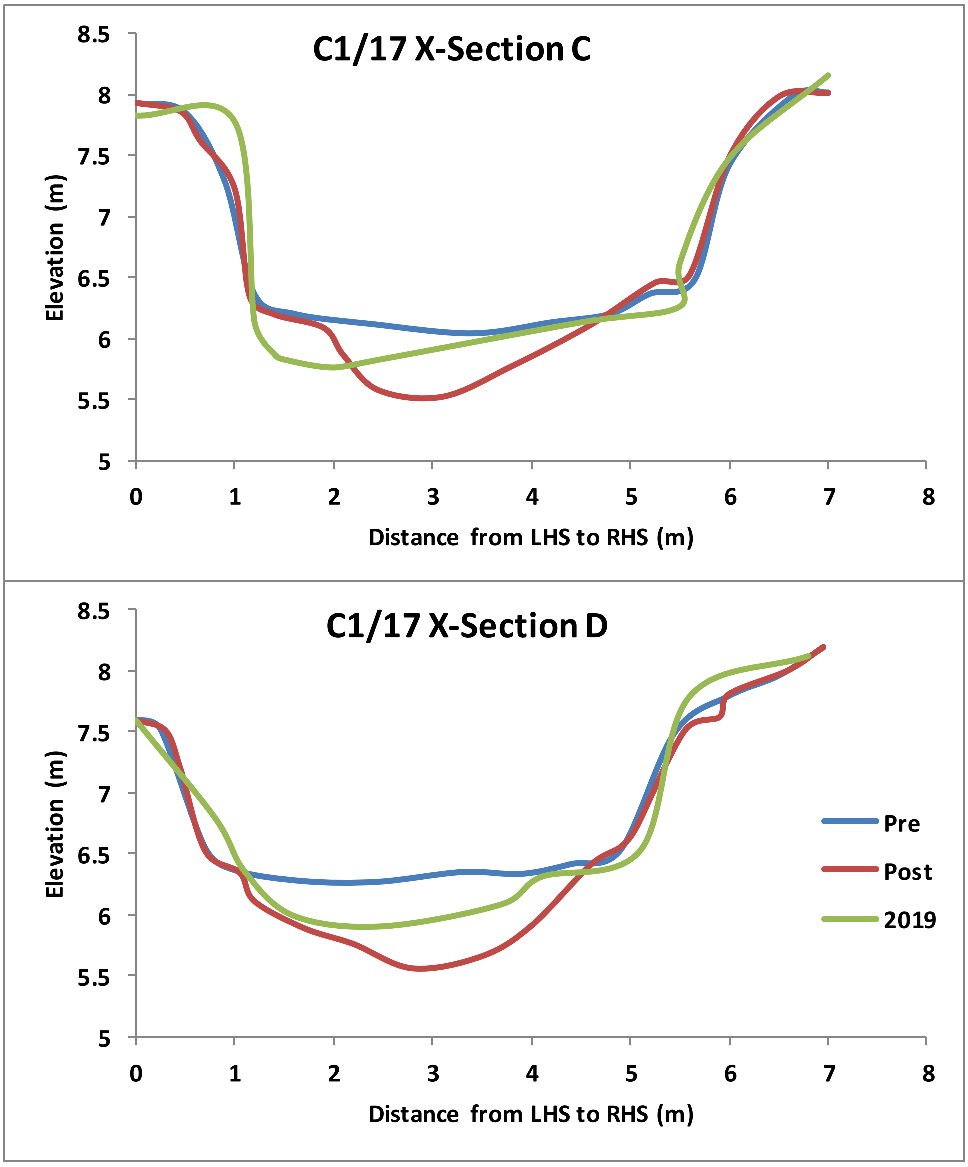


Figure 5.4 Two cross-sections at pools C and D surveyed pre- and post-enhanced maintenance works in 2007 and repeated during the revisit in 2019.

5.1.4 Conclusion

The continuing presence of the excavated pools and riffles is an indication that the bed material was suitable for these works i.e. that the material was suitable for digging in and that it would retain its form over time. The bed material in this channel was one of hard clay with gravels of various sizes and small boulders widespread in it. Softer bed materials such as marls, sands and peat or a mix of such material would not be suited to this excavation strategy. The success of this experimental project was due to several factors, all of which are relevant:

- Suitable bed gradient to facilitate sediment transport and retention of pool 'cleaning' effect. Local gradient in the experimental zone was 0.4%, well in excess of a working value of 0.15% considered suitable for experimental instream works (O' Grady and Curtin 1993)
- Suitable bed material that would permit initial excavation and, subsequently, the retention of the 'form' of the digging
- Agreed overall plan in regard to frequency of pool excavation and depth of excavation
- Expertise of the OPW crew in supervision and execution of the digging process

The outcomes here support the contention of OPW engineers at the time that the initial EDM study was being trialled in the early 1990s. A similar trial on the River Dee main stem in Co. Meath, in a gravel bed channel, was also successful, in terms of longevity, over a 5-year period of study (1990-95). The OPW engineers were satisfied that this strategy had a merit in the overall context of:

- Low / zero cost as the machine and crew would be on site
- No negative impact on channel conveyance as the works are, essentially, below the level of the design channel bed
- Opportunistic strategy available to skilled drivers comfortable at 'reading' a channel
- If pools became partly filled in, as here in the Clonshire, these too could be 'maintained' sensitively in subsequent rounds of channel maintenance
- No spoil to be removed as the contents of the digging become the shallow riffle area downstream

This repeat survey shows the importance of bed excavation, and when undertaken in a channel with suitable substrate, the pools/riffles remain in the channel bed for years. Excavating the channel creates a diversity of flow types and habitat beneficial to fauna in the riverine systems and its use in maintenance by OPW is consistent with WFD requirements.

5.2 Dungolman

5.2.1 Background

The Dungolman River is the name given to the upper reaches of the River Tang (OPW channel reference C8) in the Inny Catchment Drainage Scheme (Figure 5.5). The Tang is a large sub-catchment in the lower Inny.

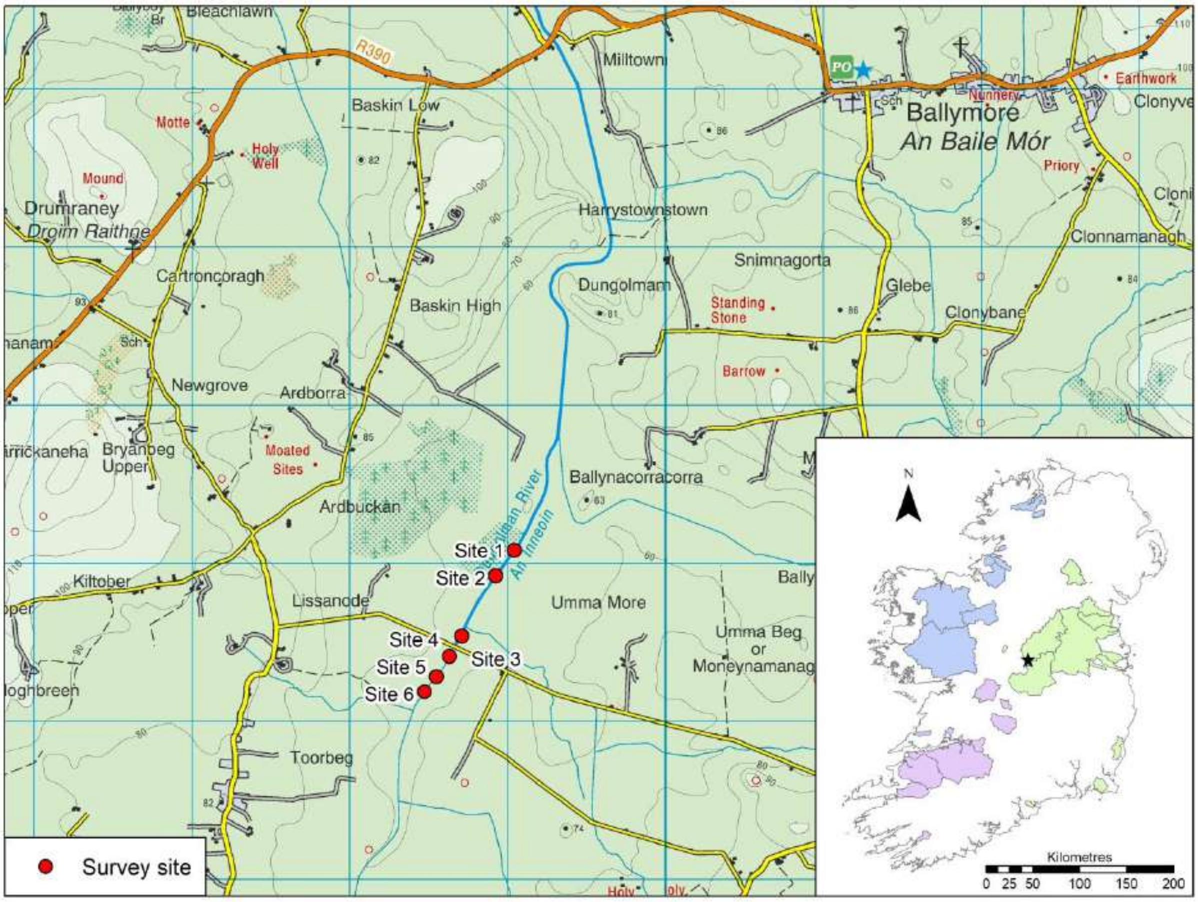


Figure 5.5 The map shows the locations of the six study sites along the Dungolman (OPW East region, inset).

Studies to examine channel maintenance impacts and scope for experimental strategies commenced here in 1993 in the townland of Ummamore in the upper reaches of the Dungolman River. The uniform trapezoidal form excavated in the original drainage works in 1960-68 had become altered over time with clear evidence of the development of a lateral berm or shelf along one side of the channel. The overall impression was one where a channel had been 'over-excavated' in the arterial drainage scheme and the increased base width had allowed sediment deposition to occur laterally. The sediment had become stabilised with vegetation, particularly the tall emergent grass *Phalaris* and this consolidation allowed further sediment deposition to occur. The net impact was to create a 2-stage channel with a narrower, deeper inset wetted channel available for summer flows or low flows and a shelf area that could be over-topped in elevated flows.

From a fisheries perspective, the narrowing effect was considered beneficial, providing a degree of depth, along with shading, from vegetation overhang, for resident brown trout. However, the stage level of the berm was commonly much higher than that necessary to retain the narrowing effect. From an OPW perspective, the berm formations were clearly impacting on the available cross-sectional area for conveyance. The agreed experimental strategy involved 'topping' the berm, where the excavator bucket used the low-flow water level prevailing at the time of maintenance as a guide and dug horizontally from this level into the berm area. The lateral digging extended back to the bank slope area and spoil was removed from the cross-section and placed on the bank full line.

5.2.2 Survey

The initial study of 1993-1996 involved three treatments:

- experimental berm topping, as described above (Site 3)
- standard maintenance, where berm could be removed or modified as per routine (Site 4)
- control site, no maintenance applied (Site 5)

The initial fisheries investigations at each site involved:

- electro-fishing survey – reported on in 2017 EREP report (Coghlan *et al.,* 2018)
- collection of physical habitat variables including width and depth data at specific transects
- vegetation mapping of a 25m-long section of berm and instream area in each site
- collection of cross-section data via levelling survey in each treatment

This initial data collection was undertaken prior to maintenance and annually for a series of years thereafter.

A series of subsequent maintenance events in the late 1990s and in 2000 in this section of the Dungolman River facilitated return surveys with an expansion of treatment sites, while retaining the original three sites (Sites 3, 4 and 5). The monitoring programme continued with data collection into 2002. The return survey in 2017 was undertaken, in part, as a facet of the overall catchment-wide survey of the Inny undertaken in the EREP study, and partly to draw the Dungolman into a network of long-term study sites, where extended data series could be collected. The survey in 2017 involved fish surveys and repeat physical surveys, recording wetted widths and depths. A detailed levelling survey, intended to repeat all of the cross-sections previously levelled across 6 study locations, was commenced in 2017 and completed in 2018.

This review provides an overview and traces a consistent series of cross sections and the impacts of maintenance on these. A graphical record is presented, along with images, for some locations and dimensional data for cross-sections are also provided.

Maintenance options proposed in 2000 prior to maintenance:

- Complete removal of berm at bed level to recreate the trapezoidal form and an open channel (Sites 1-2)
- Narrowing of berm by approximately 50% in width, retaining the vertical height and integrity of plant community on the remaining portion, the excavation being done to create or retain the vertical face that provides depth at waters edge (Sites 1-2)
- Topping of berm from just above the low flow summer level, the topping to extend in width from the waters edge to the foot of the bank slope (Site 3)
- Topping as above but with retention of the sod of the tall emergent grass *Phalaris* from the waters edge of the berm and its re-instating after the experimental length of berm has been topped (Site 3)
- Retention of the ‘standard maintenance’ Site 4 of 1993-99 as a control to continue monitoring the rate of recovery of the berm and vegetation community
- Retention of the ‘control’ Site 5 of 1993-99 as a control or long-term unaltered site
- The addition of Site 6 as an additional control area, upstream of Site 5

The three new sites, Sites 1, 2 and 6, were similar in terms of development and status of berms and of the plant assemblages growing on them: *Sparganium erectum*, *Iris*, *Phalaris*, *Epilobium* with *Mentha* and *Apium* as understorey elements.

5.2.3 Results: impact on cross-sectional form

Sites 1 & 2

Maintenance work at Sites 1 and 2 implemented significant berm size reduction or, in some cases, complete removal (Figure 5.6 & Figure 5.7). Evidence of a significant berm is clear in 2000 prior to maintenance and this is largely removed in the 2001, post-maintenance repeat survey. In addition, an element of channel deepening is evident in some profiles. In the period 2001-18 a degree of re-profiling has occurred with a more vertical face to the wetted left bank and small re-development of a berm. The extent of the excavation and berm removal in the 2000 event has substantially reduced any scope for significant berm development.

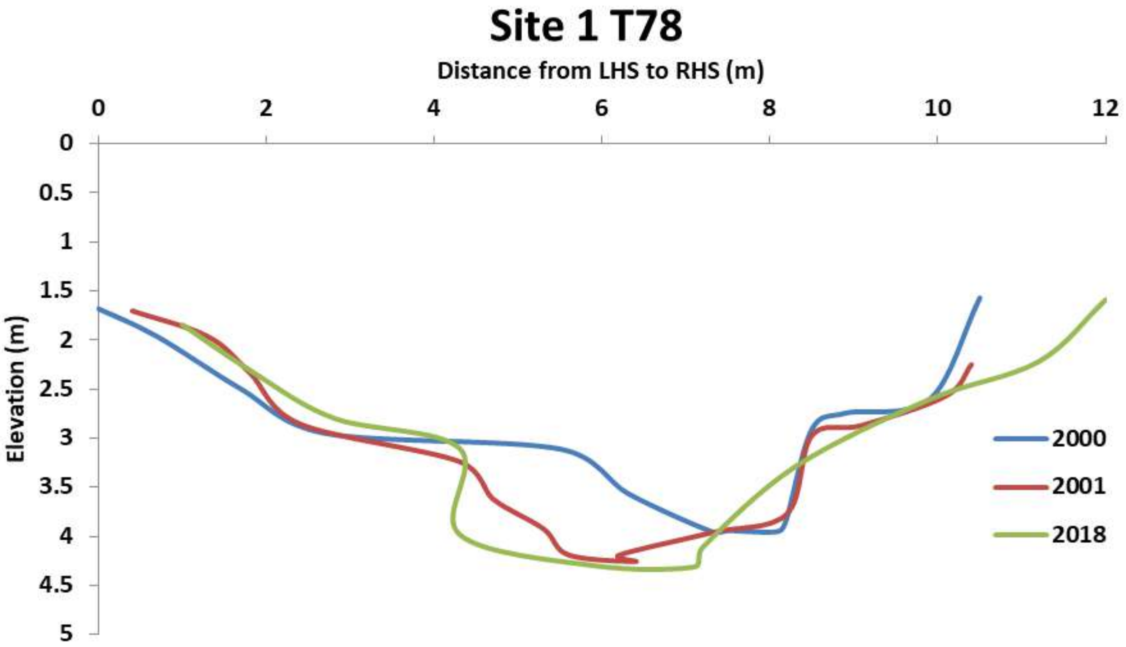


Figure 5.6 Changes to cross-sectional form at representative location in Site 1 pre- and post-maintenance and in longer term.

A similar pattern was observed in Site 2, with clear re-profiling and loss of berm between 2000 and 2001 with subsequent re-profiling up to 2018 with a vertical wetted left bank area. However, the degree of excavation from the 2000 event has not facilitated any new berm development.

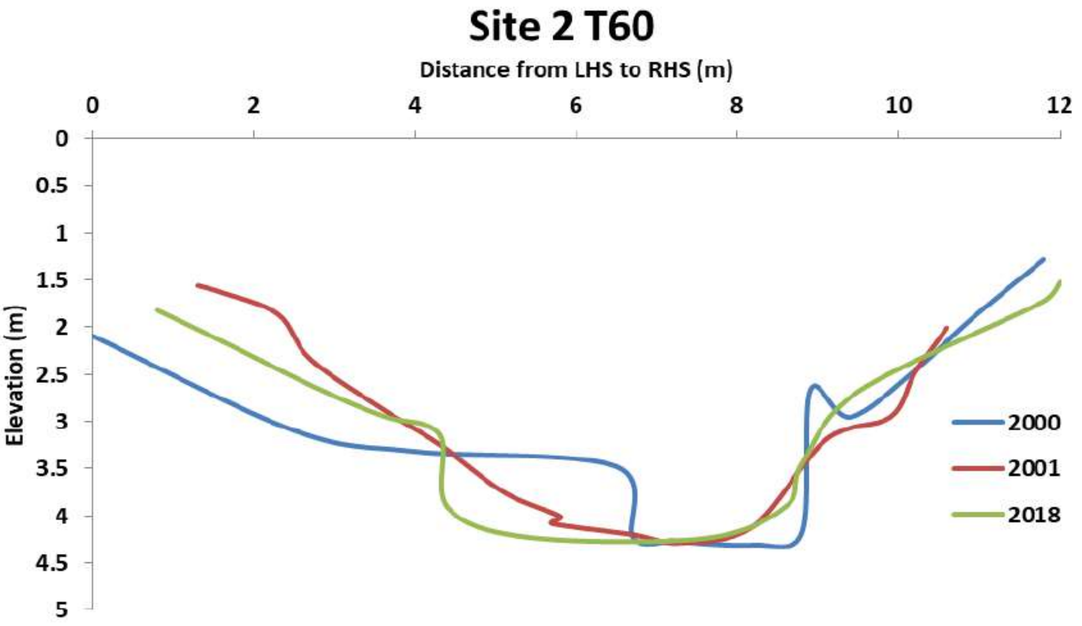


Figure 5.7 Changes to cross-sectional form at representative location in Site 2 pre- and post-maintenance and in longer term.

Sites 3, 4 & 5

The original survey sites at 3, 4 and 5 were levelled for cross-sections from the initial pre-maintenance survey in 1993. Changes in cross-sectional form and dimensional elements were examined here over three time slots – 1996, 2001 and 2017/18.The initial experimental work in 1993 led to the 'berm-topping' strategy rolled out in 1996. A subsequent maintenance programme in 2000 had a series of options available, listed above. As seen in Sites 1 and 2, quite radical berm removal was undertaken there. Alterations were also undertaken at Sites 3, 4 and 5. The graphics presented do not sit perfectly one on the other, although re-taken at the same locations. However, it is considered that the overall forms and changes of form represent actual situations at the time of survey.

There was evidence of berm removal at the Site 3 Experimental in 2001 (Figure 5.8) with loss of the narrowing effect on the inset channel and leading to increased channel width and reduced water depth. There was little evidence of berm re-development up to 2017.

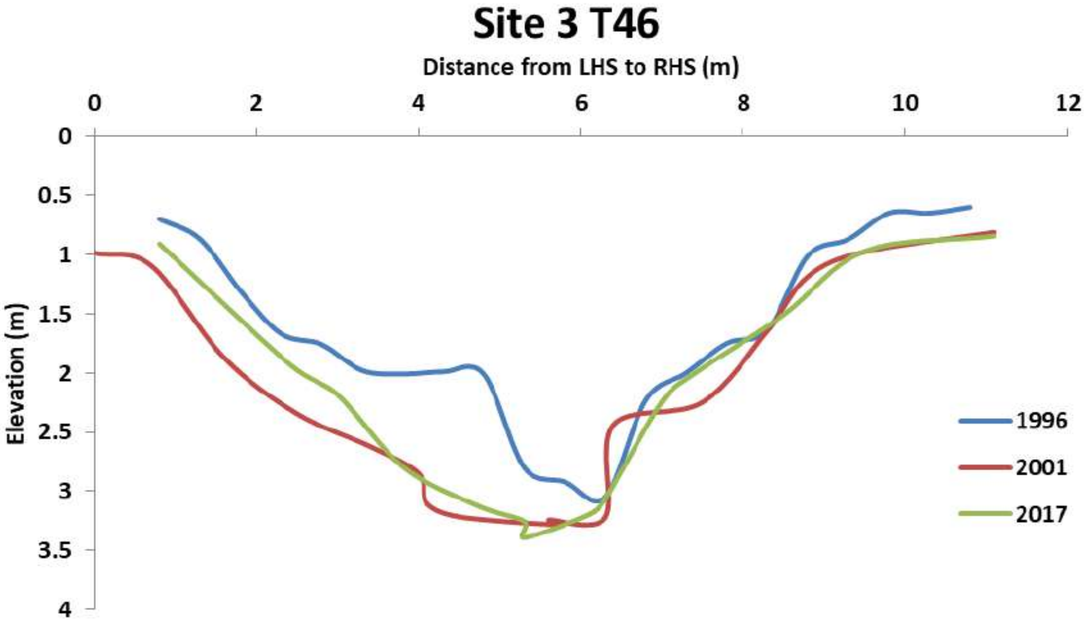


Figure 5.8 Changes to cross-sectional form at Site 3 (Experimental) with (a) berm evident in 1996 and removed in the 2001 maintenance and (b) little evidence of berm re-development up to 2017.

Site 5 or Control site was, despite its title, impacted on in the 2000 maintenance event to some degree. The data show, at one cross-section, that the berm was completely removed (Figure 5.9) leading to a substantially widened wetted channel in 2001. However, in the re-survey of 2018 there was evidence of a degree of re-formation of the berm on the left side of the channel and an encroachment from the right side, leading to a narrowing of the wetted width.

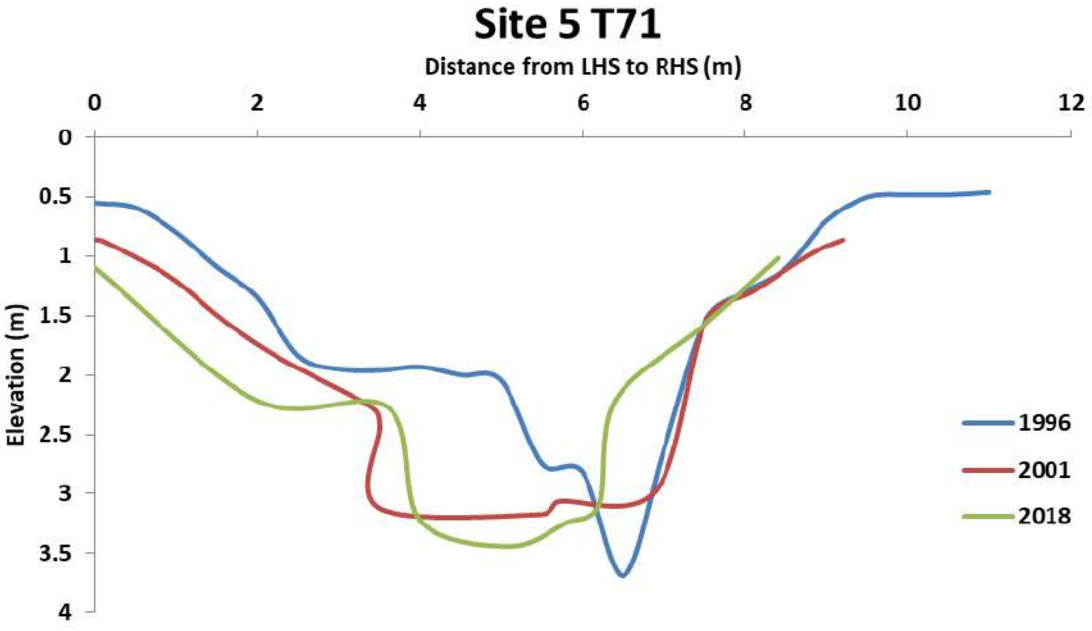


Figure 5.9 Changes to cross-sectional form at Site 5 (Control) with (a) berm evident in 1996 and removed in the 2001 maintenance and (b) evidence of berm re-development and narrowing of wetted channel up to 2018.

5.2.4 Results: dimensional examination of maintenance impacts

An overview of cross-sectional data from sites 3, 4 and 5 using the RIVERMorph^{TM} software generated a series of dimensional values or attributes of each cross section. For the three sites, four representative cross sections were surveyed in each of the years 1996, 2001 and 2017/18. Thus four replicates were available for a statistical analysis (Figure 5.10).

The mean values, with standard deviation, for each site showed a degree of fluctuation in values that might not be expected. It is surprising that the control (Site 5) showed an increase in cross-sectional area in 2001 following maintenance. This indicates that some degree of maintenance may actually have taken place at this time. Mean values for all the variables measured showed an increase in 2001, following maintenance, over the 1996 pre-maintenance data and mean values reduced by 2017/18 to levels similar to the 1996 pre-works figures. This overview impression points to a degree of removal of materials by the 2001 survey, with some bed desilting, berm manipulation and bank slope re-profiling. The reversal of this trend by 2017/18 points to a degree of dynamic process having occurred, with some berm re-formation. Fencing on the left bank at the various sites, including Sites 1 and 2 would have served to eliminate livestock, for the most part. It is likely that poaching by livestock (Figure 5.11) would have contributed to berm instability over a period of years. Evidence of this was clear in Site 4 (Standard Maintenance) in 2018, where cattle still had access and where the channel had been heavily encroached by trampling and collapse of the berm (Figure

5.11). Site 4 showed the widest variation in mean values for the cross-sectional dimensions measured, over the period from 1996 to 2018 (Figure 5.10).

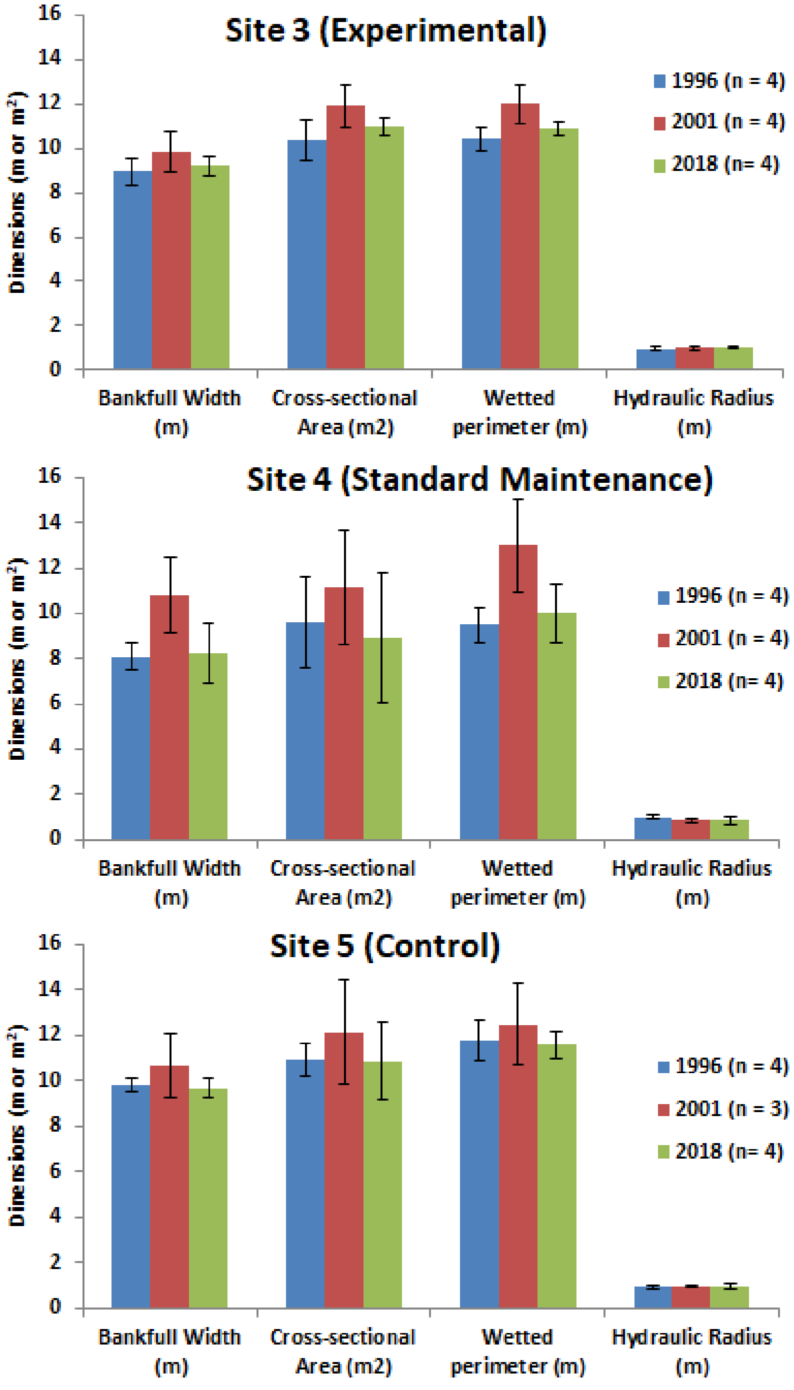


Figure 5.10 Mean (with Standard Deviation) for cross-sectional dimensions for three sites in the R. Dungolman, measured in 1996, 2001and 2017/18.

Figure 5.11 Dungolman Site 4 (2018) showing cattle ingress into the cross section despite robust fencing.

The cross-sectional area data was examined on a site-by-site basis with between-year comparison using the Mann-Whitney U test. The median cross-sectional area showed a significant increase in the Site 3 (Experimental) between the 1996 and 2001 survey. Apart from this, all between-year paired comparisons within any site were not significantly different.

The analysis was repeated with a comparison of cross-sectional area between sites in any one year i.e. replicates from the control were compared with the experimental and with the standard maintenance sites within each year. The Mann-Whitney U test was again used. No significant differences were detected between cross-sectional areas from any pairing of sites within any of the survey years.

The overall cross-sectional areas in the samples all appeared to belong to a larger ‘population’ of cross-sections i.e. all appeared to lie within the broad design specification generated by the OPW at the time of excavation design for this channel. Such an outcome may support the notion that flood conveyance has not been reduced or adversely impacted by berm development over time, from the point-of-view of cross-sectional area. However, the berm structures or 2-stage channel created is considered to impact on conveyance. This arises in part from the development of vegetation on the berm, increasing the Manning’s roughness element for the flood flow condition. In the case of the Dungolman, the vegetation on the berms is of the ‘soft’ variety, consisting of tall emergent grasses and perennial flowering plants. There is no evidence of woody vegetation or tree cover developing on the berms.

5.2.5 Conclusion

While the analysis of cross-sectional area above identified a ‘unity’ of area, between the different treatments and years, the different excavations at Sites 3, 4 and 5 clearly showed different physical forms, in regard to extent of berm developed or retained or removed. It is the view of IFI that these different physical forms have a benefit for biota, including the brown trout populations resident instream and the diversity of bankside vegetation growing on the berm areas.

Berm loss was evident in all sites following maintenance and the extent of berm re-development varied amongst the sites. Berm loss had the effect of widening the inset channel and leading to increased channel width and reduced water depths. Such alterations are not beneficial to fish species, particularly in the context of climate change and warming of waters. Likewise, the loss of the vegetation overhang from the berms would also contribute to warming of the widened instream channel.

The changes evident in the various paired cross-sectional outlines between 1996 and 2018 indicate a range of factors. These included impact of maintenance in reducing the berms, contrary to the recently published guidance on Topic 7 – Berm management – of the OPW’s guidance (Brew and Gilligan, 2019). It should be noted that the initial maintenance in the early 2000s was prior to this environmental guidance and case studies such as the Dungolman contributed to the evolution of the 10 steps to environmentally-friendly maintenance protocol. There was also evidence of river dynamics, even in a relatively small channel such as the Dungolman, with low gradient and relatively low volume discharge, with evidence of berm redevelopment in some cases suggesting on-going lateral deposition of fine sediments.

5.3 Tullamore Silver

5.3.1 Background

The Tullamore Silver River (OPW channel reference C9(1)) drains an area of 76.9km^2 and is 26km in length. It flows in a westerly direction and joins the Clodiagh River downstream of Rahan in Co. Offaly. In its lower 5km, downstream of Aharney Bridge, the river has a low gradient of circa 0.1% and is considered a lowland meandering channel. In this section of channel, substrate type is dominated by a clay bed of firm grey, cohesive material. The Brosna arterial drainage scheme (1948-55) created a channel displaying a typical trapezoidal cross-sectional form along with extended segments of uniform longitudinal profile. The channel was realigned extensively with meanders removed. The low gradient, uniform character and absence of tree cover facilitates extensive growth of the tall emergent plant *Sparganium erectum* or 'flaggers'. Extensive growth across the entire channel impedes conveyance of summer flows. Although problematic, this form of vegetation dies naturally in autumn. This channel supports a population of brown trout and pike along with smaller fish species such as minnow and sticklebacks.

The initial Environmental Drainage Maintenance (EDM) study of OPW and IFI (1990-2007) undertook investigations on the lower reaches of the Tullamore Silver with a series of study sites examined in regard to management of the *Sparganium erectum* vegetation (King 1996).

Trial sites involving experimental and standard maintenance approaches were established. Maintenance diggings were undertaken by OPW and the impacts on fish, vegetation and physical habitat were studied. Overall, studies were undertaken in the period from 1990 to 1997. A repeat investigation of the fish community, as part of the EREP long-term studies, was undertaken in 2016. To complement this, a repeat survey to examine changes in the channel riparian and instream features over 22 years was undertaken in 2019. A total of 16 cross-sections, spread over 7 sites, were surveyed in 1997 and each re-surveyed in 2019 (Figure 5.12). The sites are all located on a fourth order section of the Tullamore Silver over a channel length of 5km. Descriptions and photographs from the 1997 survey were used to re-locate the individual cross-sections. In addition, one of the surveyors from the 1997 survey was involved in the 2019 repeat surveys.

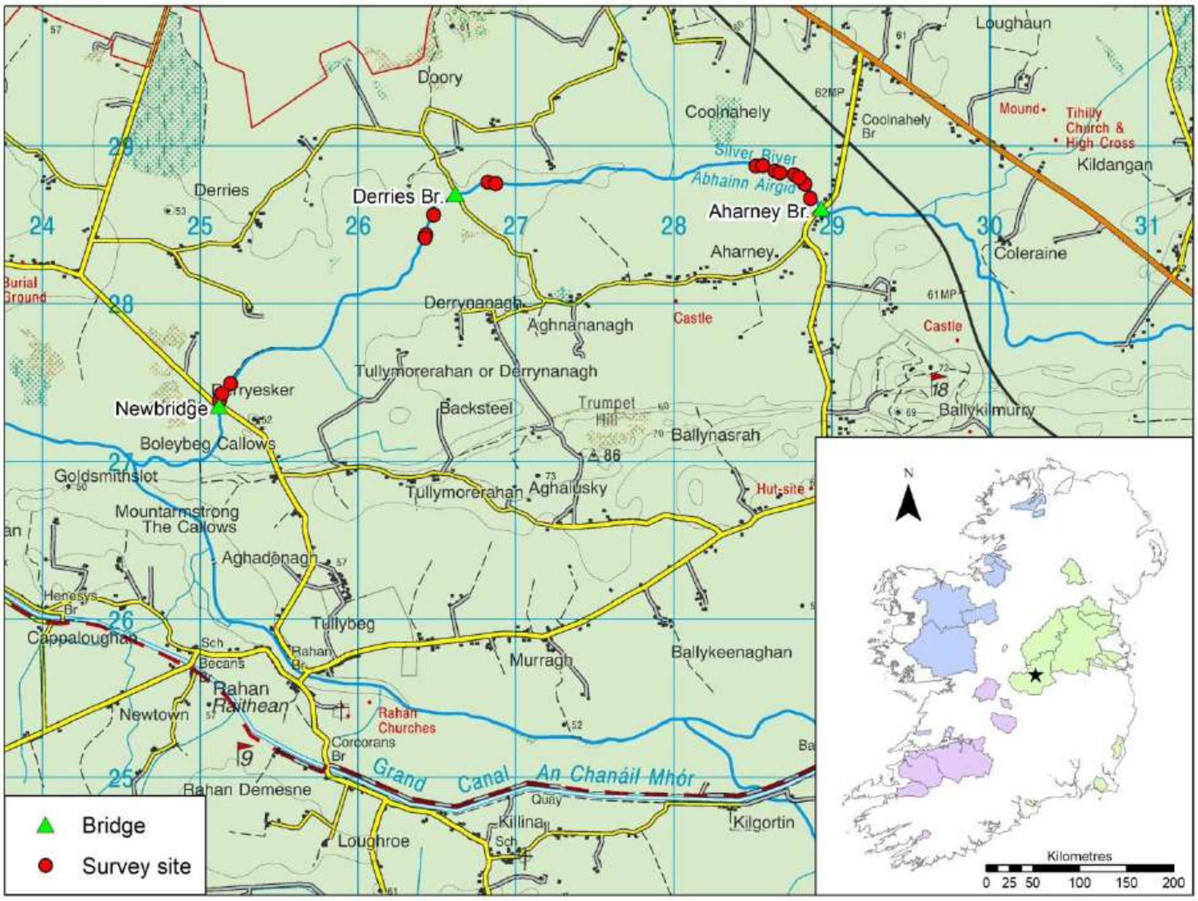


Figure 5.12 The map shows the locations of the study sites along the Tullamore Silver (OPE East region, inset).

5.3.2 Survey

The underlying experimental idea in 1990, within the EDM study, was to alter the shape of the channel cross-section in one pilot site within the Tullamore Silver, changing the flat or horizontal channel bed to a sloped one. This was to be done by over digging on one side and moving the excavated spoil to the wetted margin on the other side, thereby creating a wedge-shaped cross-section. Fundamentally, the cross-sectional area and bank-full width would not be altered but the cross-sectional form would be changed. The over-deepening idea was intended to see if the growth of the tall emergent flaggers could be confined to the shallower side of the cross-section and thereby leave an open-channel flow in the deeper side of the cross-section. If successful, this strategy might serve to reduce maintenance requirements, in regard to managing flagger growth, and might also serve to provide a more optimal open-channel habitat for resident brown trout.

The initial study, commenced in 1990, examined:

- one experimentally-treated channel segment (Site 35) of short length (<100 m)

- a site given standard maintenance treatment (Site 2)
- A further shallow-water location (Site 1) where the vegetation was dominated by water cress vegetation.

The impact of the various digging strategies on the channel vegetation was tracked over an initial 4-year period from 1990 to 1994 (King 1996).

Additional sites were surveyed in successive years and in the context of repeat channel maintenance events. In successive maintenance events, an increased use was made of the experimental digging strategy. The locations of such additional experimental diggings were at the discretion of the resident foreman and his driver crew and were, in part, influenced by local conditions of water depth, bed material and prevalence of the open-water growths of *Sparganium erectum* or ‘flaggers’. Successful implementation of the experimental digging was evidenced in areas where there was an extended open passage of flow through marginal stands of flaggers in summer (Figure 5.13). The aim of the 2019 survey was to repeat the series of cross-sections levelled in 1997 and to examine both cross-sectional form or shape as well as cross-sectional dimensions from the two periods, in order to examine the duration or longevity of the experimental approach and its effect on instream vegetation.

Figure 5.13 Tullamore Silver approx. 2007, showing open channel flow through a wedge-shaped cross section excavated in maintenance.

The uniform nature of the topography and the absence of any large tributaries entering the Tullamore Silver River within the boundaries of the study area (Newbridge to Aharney Bridge) indicated that the OPW design for gradient and cross-sections would remain consistent over this channel section. This assumption underlay decisions to take limited numbers of replicate cross-sections in study sites. A maximum of 3 such cross-sections were taken at Sites 35 (original Experimental site) at Site 9 and at Site 10. Pairs of cross-sections were taken at Site 2 (original Standard Maintenance site) and at Site 4 (an additional Standard Maintenance site of 1990).

The data collected from both years were analysed using RIVERmorph^{TM}. The software constructs cross-section figures based on the elevation measurements recorded at each site, in 1997 and 2019. These cross-sectional figures illustrate if changes have occurred at each cross-section during the interim period between surveys. Features change over time due to natural hydromorphological processes such as erosion and deposition or human interference including drainage works.

The RIVERmorph^{TM} programme also generates an output table with summary data for each cross section. The data table includes dimensional data, including bank full width, cross-sectional area, wetted perimeter and hydraulic radius. The data was used to make statistical comparison between the two full data sets, for 1997 and for 2019 i.e. an overall between-year comparison of dimensional data. In addition, the dimensions were compared for between-year differences at specific sites. For the purposes of this report 3 of the sections will be reported on in detail:

- Experimental Site 35
- Standard Maintenance sites 2 and 4 (paired up for inter-annual comparison)
- Site 10, where the channel traditionally presented as being more ‘entrenched’ and had a degree of berm formation along one bank

A levelling telescope and 5m engineering staff were used in the levelling surveys in all years. The survey in 1997 and in previous years were undertaken via the taking of vertical readings at set intervals of 0.5m across each transect with a metric tape stretched in the horizontal providing a spacing guide. In 2019, the upper and lower stadia readings were used to measure horizontal distance from the telescope, with all vertical readings taken at points of inflection along the line of the wetted perimeter. These differences account, in part, for imperfect alignment of paired cross-section drawings.

5.3.3 Results

The summary comparison of dimensional outputs indicated a broad similarity for individual measurements between 1997 and 2019 (Figure 5.14). The series of cross-sections generated 16 sets of measurements for each year.

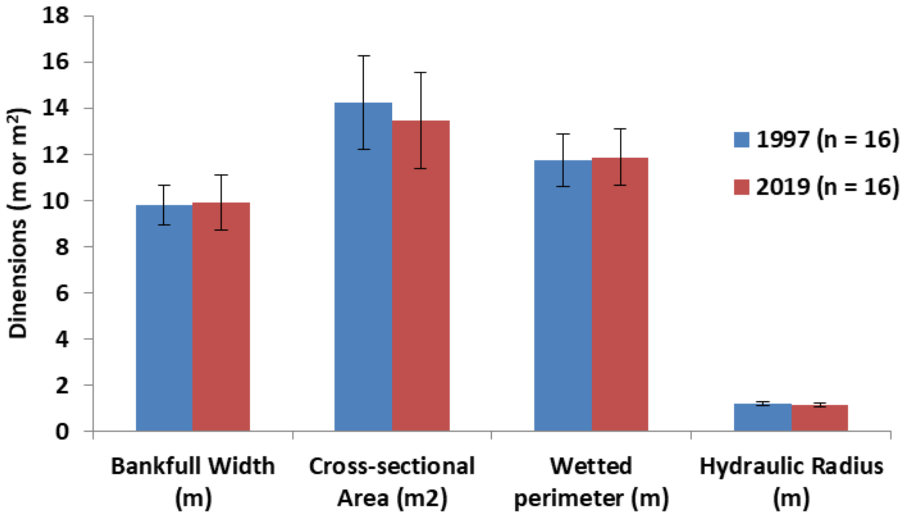


Figure 5.14 Comparison of four cross-sectional dimensions from sites (n=16) in R. Tullamore Silver measured in 1997 and 2019.

There was no significant difference (Mann Whitney U test) for the paired measurements for each of (a) bankfull width, (b) cross-sectional area and (c) wetted perimeter. However, a significant difference was detected for hydraulic radius, with the value being higher in 1997 than in 2019 (Table 5.2).These results point to a consistency of 'performance' by OPW insofar as the maintenance undertaken had not led to any increases in channel cross-section, as measured by bankfull width or cross-sectional area. Modifications to the cross-sectional form, by way of experimental diggings agreed with IFI, would not appear to have adversely impacted on the conveyance design of the channel.

Table 5.2 Statistical comparison of four cross-sectional dimensions from sites (n=16) in R. Tullamore Silver measured in 1997 and 2019.

	Significance	p	Mann Whiney U	n1	n2
Bankfull Width (m)	NS	0.507	127.5	16	16
Bankfull Area (sq m)	NS	0.112	95	16	16
Wetted perimeter (m)	NS	0.28	112	16	16
Hydraulic Radius (m)	*	0.0015	50.9	16	16

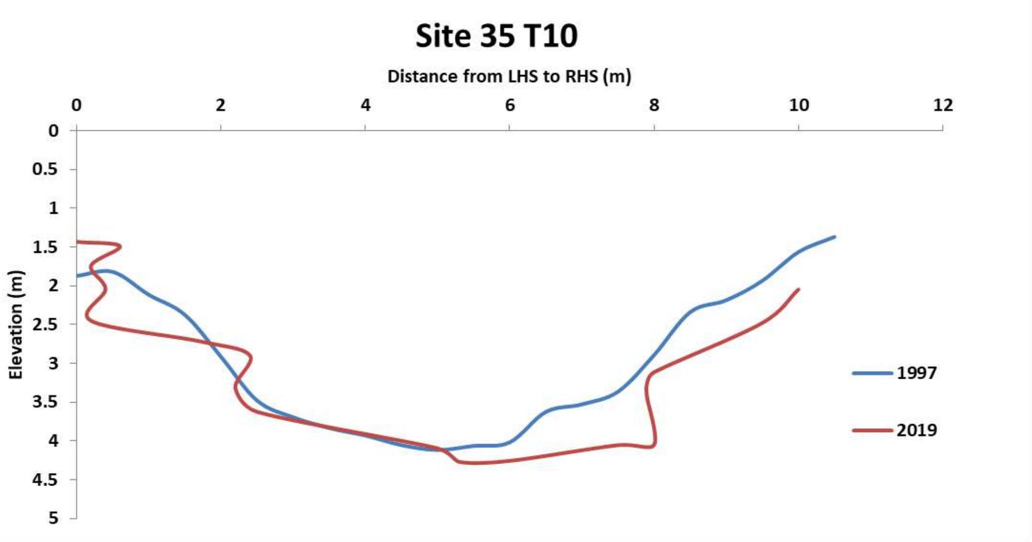
Figure 5.15 Electro-fishing following the removal of instream flaggers at site 9 in 2016. Note prevalence of berm on left bank (OPW machine working bank).

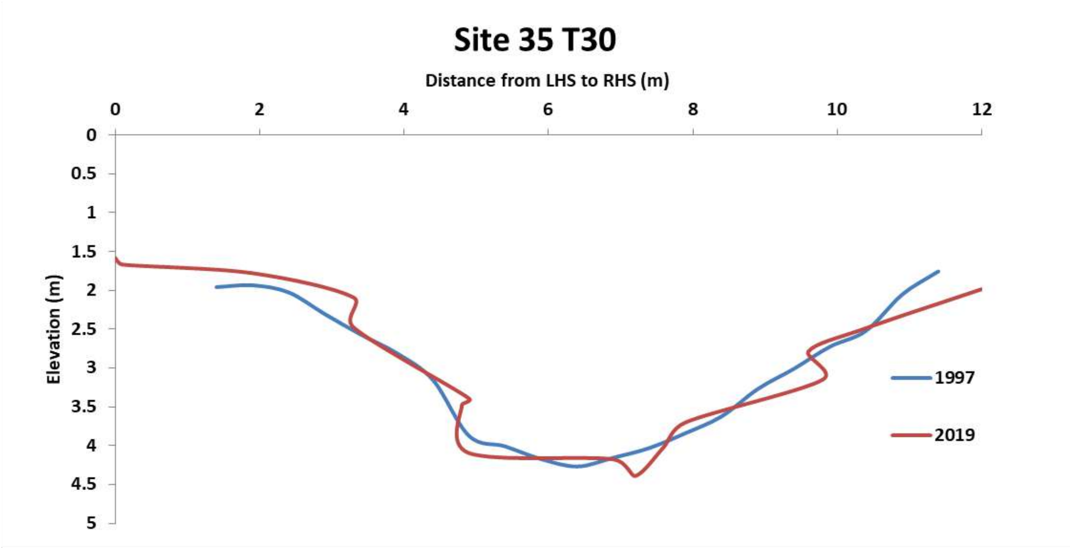
Site 35 (experimental site):

This was the original experimental site where the bed was over dug on the right hand side and the spoil placed along the left hand side to create wedge-shaped cross section. Photo and levelling evidence indicated that this form remained intact during the early 1990s.

The levelling survey in 1997 indicated that the trapezoidal form continued to remain modified from the drainage scheme design, particularly in Transect 10 and 30 (Figure 5.16). The bed material in the study areas in the Tullamore Silver is cohesive grey clay that can retain its shape when modified. However, some degree of loss of 'definition' may be inevitable with time. The 2019 survey indicated a broad similarity of form with a shelving or low berm area evident on the left bank at T85 and a gradual sloping of the left bank from the channel bed compared to a more steep slope on the right bank (Figure 5.16). Berm re-development is also evident at other sites in this section of the Tullamore Silver (Figure 5.15).

The cross-section dimensions generated from RiverMORPH^{TM} were compared for the two years. The number of replicates (n=3) was small for comparison. No significant differences were recorded between the dimensional data for the two survey periods.





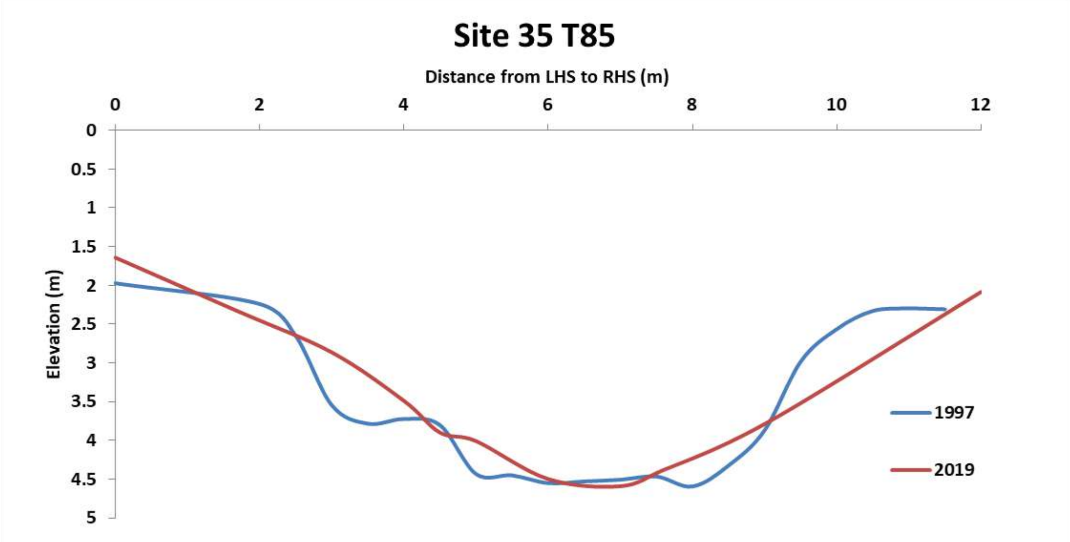


Figure 5.16 Cross-sectional form at three transects from Site 35 (original experimental site of 1990) levelled in 1997 and 2019.

Site 2 (Standard Maintenance site of 1990) and Site 4 (additional Standard Maintenance site):

Site 2 was the original Standard Maintenance site from the 1990 study where ‘normal’ or ‘standard’ maintenance work was undertaken. No new diggings, desilting or spoil management proposals were planned for here. Site 4 was treated in the same manner in 1990.

Levelling surveys in the early 1990s, following the 1990 maintenance event, indicated that Sites 2 and 4 were primarily deep-water (~1m) in the open channel but that the left side of the channel, where the maintenance machine had operated, had the appearance of a degree of slope both within the wetted channel and on the bank slope. In other words, the trapezoidal form was being somewhat modified via the standard maintenance.

The levelling survey in 1997 indicated that the trapezoidal form continued to remain modified (Figure 5.17). Even allowing for the misalignment of the graphics there is limited evidence in change of form over the 22-year period at Site 2. The small degree of berm formation on the right bank and the general sloping of the left bank are similar between years indicating a degree of more ‘robust’ machine intervention on the right side and a lesser level of intervention on the left side.

The two transects from Site 4 both showed a degree of contraction, due to deposition at the right side of the channel at a low level, between the 1997 and the 2019 surveys. The relatively uniform slope on the left side of the channel, as seen in Site 2, was also apparent in the two transects from Site 4.

The four cross-section dimensions generated from RiverMORPH^{TM}, were compared for the pooled set of 4 cross-sections – two from each site (2 and 4) for the two years. The number of replicates (n=4) was small for comparison. No significant differences were recorded between the dimensional data for the two survey periods.

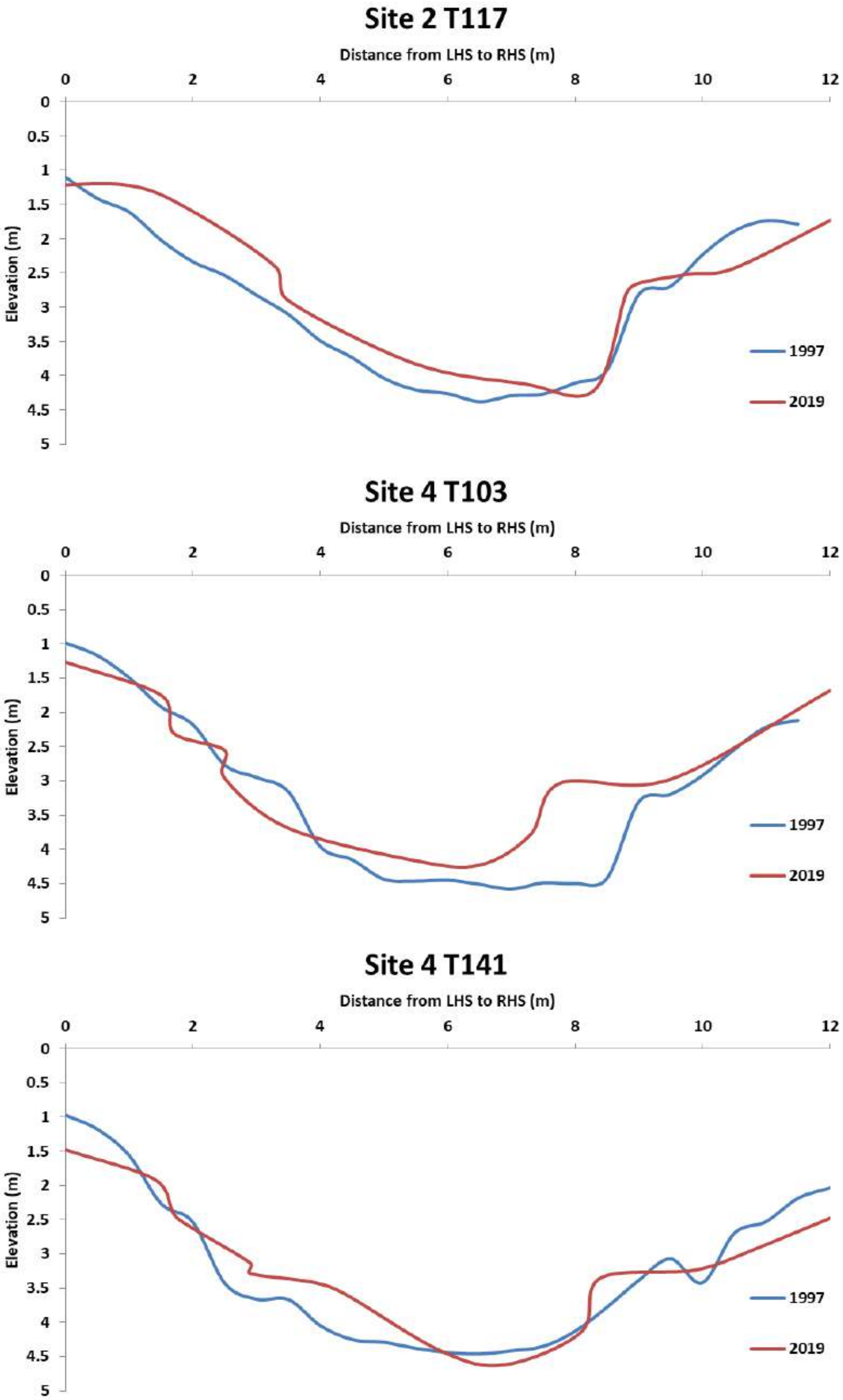


Figure 5.17 Cross-sectional form at one transect from Site 2 (original standard maintenance site of 1990) and two transects from Site 4 (also given standard maintenance) levelled in 1997 and 2019.

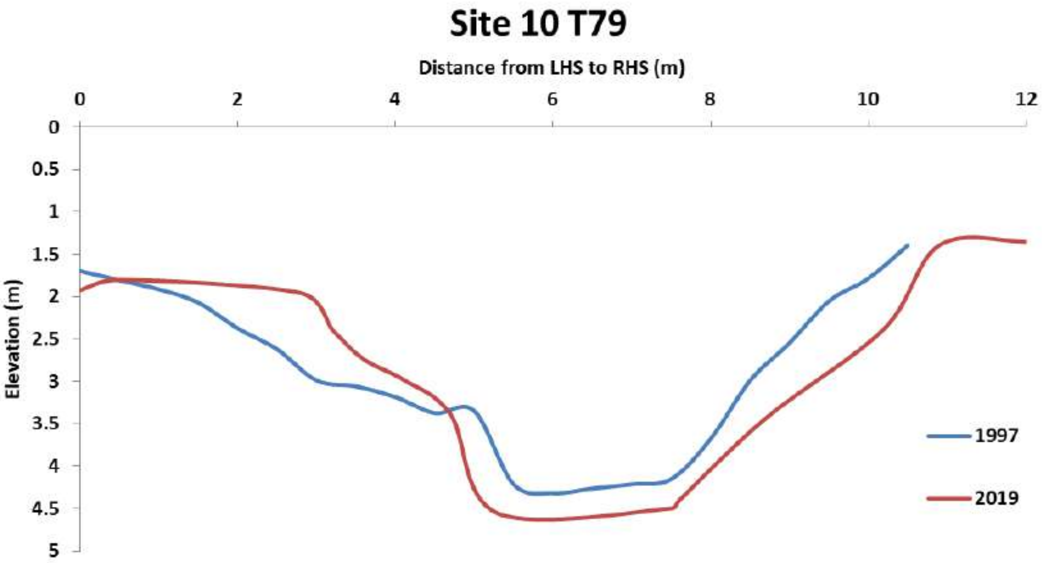
Site 10 (entrenched with berm formation):

This site was located in a straight section of channel upstream of Newbridge. It was highly photogenic as a consistent photo record could be compiled from the bridge using a dwelling house in the background as a reference (Figure 5.18). The channel cross-section presented an entrenched aspect with a reduced level of instream growth of tall emergent flaggers due to the narrow open-water flow path.

The two cross-sectional surveys presented (Figure 5.19) show minor changes in form over the two survey years. There was evidence of maintenance impact on cross-sectional form between the 1997 and 2019 surveys, with minor widening (Figure 5.19, T79). A berm had formed along the left side and remained a consistent feature over many years since 1990. The berm and bank slopes had become vegetated up to 2019. T129 shows berm development on the right-hand side and channel narrowing. Overall there was an evident open-water flow path here and ‘flagger’ growth instream was not a major issue.

The three cross-section dimensions generated from RiverMORPH^{TM}, were compared for the two survey years (two cross-section examples are shown in Figure 5.19). The number of replicates (n=3) was small for comparison. No significant differences were recorded between the individual dimensional data pairs for the two survey periods.

Figure 5.18 Site 10 – upstream view from Newbridge following maintenance in 2016. Evidence of low berm on left bank



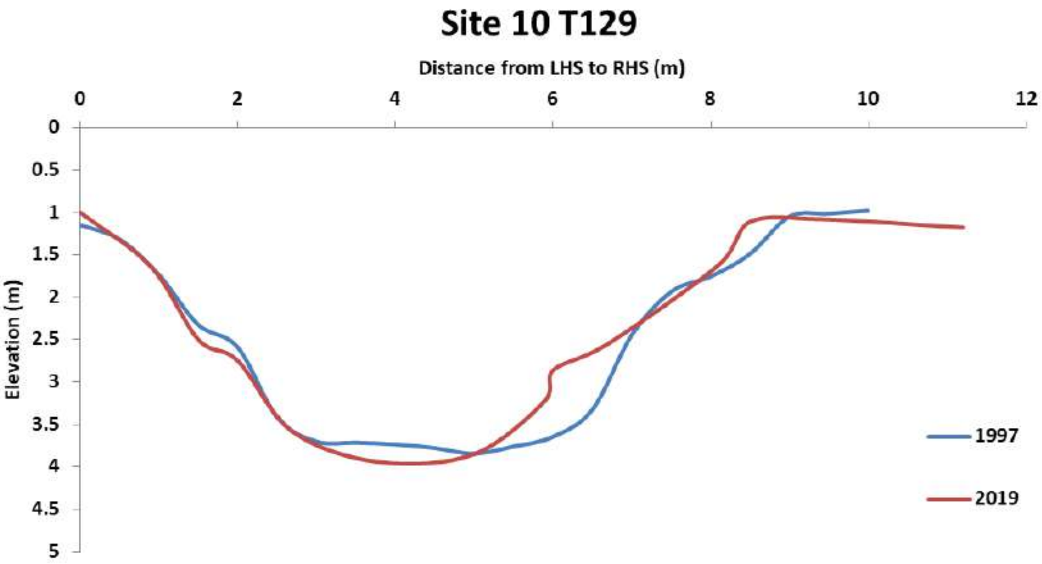


Figure 5.19 Cross-sectional form at two transects from Site 10 levelled in 1997 and 2019.

5.3.4 Conclusion

Overall there have been limited changes in the cross-sections between 1997 and 2019. The minor differences indicate that the riverine system has potential to alter habitat within its confined banks, with evidence of lateral movement and processes in those intervening years. Vegetation growth within the channel responds to these shifts and changes and, in the case of *Sparganium erectum* or 'flaggers' the vegetation can influence these responses (Gurnell *et al*., 2013).

These surveys indicate a degree of departure from the strict trapezoidal form over the period from 1990 to 2019. This is a positive reflection on the OPW personnel involved who have implemented a degree of the environmental guidance facilitating manipulation of the channel cross-section. This implementation has shown visible benefit to OPW in regard to reduced growths of flaggers and, hence, reduced maintenance effort required in this 5km section of channel. The re-profiling has not had an adverse effect on cross-sectional dimensions and, hence, on conveyance capacity. The re-profiling has altered the physical form of cross-sections and this has facilitated changes in the instream and marginal vegetation with reduced levels of flaggers and increased presence of tall marginal grasses along the channel margins. These grasses provide cover for brown trout populations in the river.

The experimental approach trialled here in 1990 and subsequently applied more extensively in this stretch has also been trialled by OPW staff in other catchment drainage schemes. The essential requirements for a successful implementation of this maintenance strategy, an element of Topic 10 in the OPW guidance, include channel bed material that has a 'robustness' or capacity to retain an altered form without any subsidence of the adjoining bank areas. Drivers have demonstrated their capacity to undertake such diggings successfully and should be encouraged by their managers to undertake these measures, where appropriate. This type of intervention in maintenance is a very practical way for OPW to improve a river hydromorphological condition – as measured in RHAT scores (Section 2.4, page 12). Hydromorphology is an important aspect of the EU Water Framework Directive, and improvements to this element can be achieved directly by OPW staff.

5.4 Summary

The examples of channel maintenance and manipulation of the cross- and longitudinal-sections presented in this chapter highlight a number of common outcomes. The bed material should be a suitable substrate type for any proposed Enhanced Maintenance (EM) measures, so that longevity will be optimised. A suitable gradient favours the success of EM strategies whereby the riffle/pool sequences created become self-cleansing over time. Regarding channel morphology, the long-term retention of pool-riffle sequences creates a diversity of flow types and habitat within the channel and this is beneficial to riverine fauna. Other physical forms such as berms have a benefit for biota, including the brown trout populations resident instream. At some sites in the Dungolman River, berm loss was attributable to maintenance. This had the effect of losing the narrowed inset channel and led to increased channel widths and reduced water depths. Moreover, any shading provided by marginal vegetation was also lost. These types of alterations are not beneficial to fish, particularly in the context of a changing climate and the associated warming of inland waterways. When left alone, many of these channels re-naturalise and attempt berm re-formation, narrowing the river corridor, showing that even within a confined corridor these rivers are dynamic.

From an OPW perspective, many of these measures have complementary benefits. For example, there is a low or possibly no cost as the machine is already in place for routine maintenance. The classic trapezoidal channel form can be altered to maintain conveyance, but improve habitat features. There is no need for spoil removal as it can be re-used within the channel. Enhanced maintenance measures can decrease the prevalence of the uniform glide. Problematic instream vegetation, such as flaggers can be carefully reduced, with marginal vegetation retained providing some cover for brown trout. These case studies presented here highlight some good practice in relation to the ‘10 steps to environmentally friendly maintenance’ (Brew and Gilligan, 2019), particularly re-profiling the channel bed and selective vegetation removal. More could be done to promote berm management as highlighted in the Dungolman example.

Good communication between OPW staff including engineers/foremen/drivers and IFI EREP staff identified the opportunities for these enhanced maintenance measures. Similar measures can be identified across all OPW regions, to the benefit of both OPW and IFI staff with learnings on all fronts. Overall, there is potential for improvement in the hydromorphological condition of drained channels across various parameters measured in the RHAT survey (Section 2.4, page 12), including channel form & flow type, channel vegetation, bank structure & stability and bank vegetation.

6 Implementation of experimental strategies, consistent with new OPW environmental guidance

In developing the outlines of the current 5-year EREP programme, OPW and IFI discussed actions and strategies that might be undertaken in channel maintenance programmes that would further contribute to habitat improvement. Implementation of the 10-point environmental guidance was seen as a key element, strongly supported by the recently-produced OPW guidance manual (Brew and Gilligan, 2019). It was proposed that a more proactive approach by OPW to implementing Topic 10 of the 10-point guidance had the capacity to bring about significant improvement in channel hydromorphology. Add-on strategies were also discussed where implementing one topic might provide an opportunity to implement some further value-added measure. One example presented was that of tree management, where tree removal would be required. This may present an opportunity to re-use the cut trees as low-level deflector structures within the wetted channel. Tree management essentially requires cutting during the appropriate temporal 'window'. For the most part this does not overlap with the 'window' for undertaking instream works. The proposal envisaged here would require retention of cut trees at the riverbank for their re-handling during the instream 'window'. This strategy would be very suited to a channel where both tree management and instream maintenance were required, with the tree work done in winter and the instream work done the following summer. Retention of cut trees and their re-use could then fit in with the summer work programme. IFI identified a number of OPW channels where this tree re-handling strategy could be implemented and an experimental study was undertaken in the River Eignagh, Moy catchment, during 2019.

The capacity for synergies between different projects being undertaken by different public authorities or by state or EU-funded projects was also reviewed by OPW and IFI. Given the involvement of IFI in the EU cross-border CatchmentCARE project, with its plans to improve hydromorphology in candidate rivers, both OPW and IFI saw a clear synergy between OPW's proposed annual channel maintenance programme in the Monaghan Blackwater, one of the listed catchments in the CatchmentCARE project, and the CatchmentCARE project itself. A walkover survey in May 2019 on the River Cor, scheduled for maintenance in 2019, involving OPW, IFI and relevant colleagues from the CatchmentCARE project identified maintenance measures consistent with enhancing hydromorphology as well as some additional experimental measures not inconsistent with Enhanced Maintenance. The team also identified the scope for CatchmentCARE to follow up on the OPW's maintenance with a fencing and discrete tree-planting programme that would be consistent with OPW's requirements. The fencing would aim at complete livestock exclusion from the channel with provision for off-line drinking troughs for livestock.

6.1 Eignagh River: installation of deflectors

The Eignagh River had been surveyed in the EDM study (2005-07) and was re-surveyed as a long-term study site in 2019 (Chapter 4, page 46), and consisted of 10 sites (Figure 6.1). Both biological and physical elements of each site were surveyed – boat fishings, canopy cover and wetted widths and depths. At the lower reaches, south of Aclare, the river drains a bog before entering the main stem of the Moy. This stretch of channel has been heavily modified due to arterial drainage, with the channel displaying all characteristics of a drained channel. The river is uniformly trapezoidal, with no diversity in the shape of the bed or banks, or of flow currents and instream substrate type.

The Eignagh was one of the channels identified in OPW-IFI planning as one where tree management had been undertaken previously and where further management could re-use the timbers removed during maintenance, for use as instream deflectors set at a low level in the channel bed and secured to the channel bed and banks. A site visit in January 2019 with the OPW resident engineer and foreman identified two candidate locations for a small-scale experiment and on-site discussion confirmed that both OPW and IFI were of same view as regards:

- type of tree to use – alders only and NOT willow
- degree of ‘trimming’ of branches etc. in order to avoid collecting river-borne trash – at discretion of OPW
- numbers and spacing of deflectors – placement and quantities agreed on-site
- imperative of secure fastening – precise mechanism to be decided by OPW, based on several options presented

OPW undertook the removal of discrete trees at the two proposed experimental sites during the relevant environmental window and had all in readiness for placement instream later in the summer, following the main IFI fish and habitat survey.

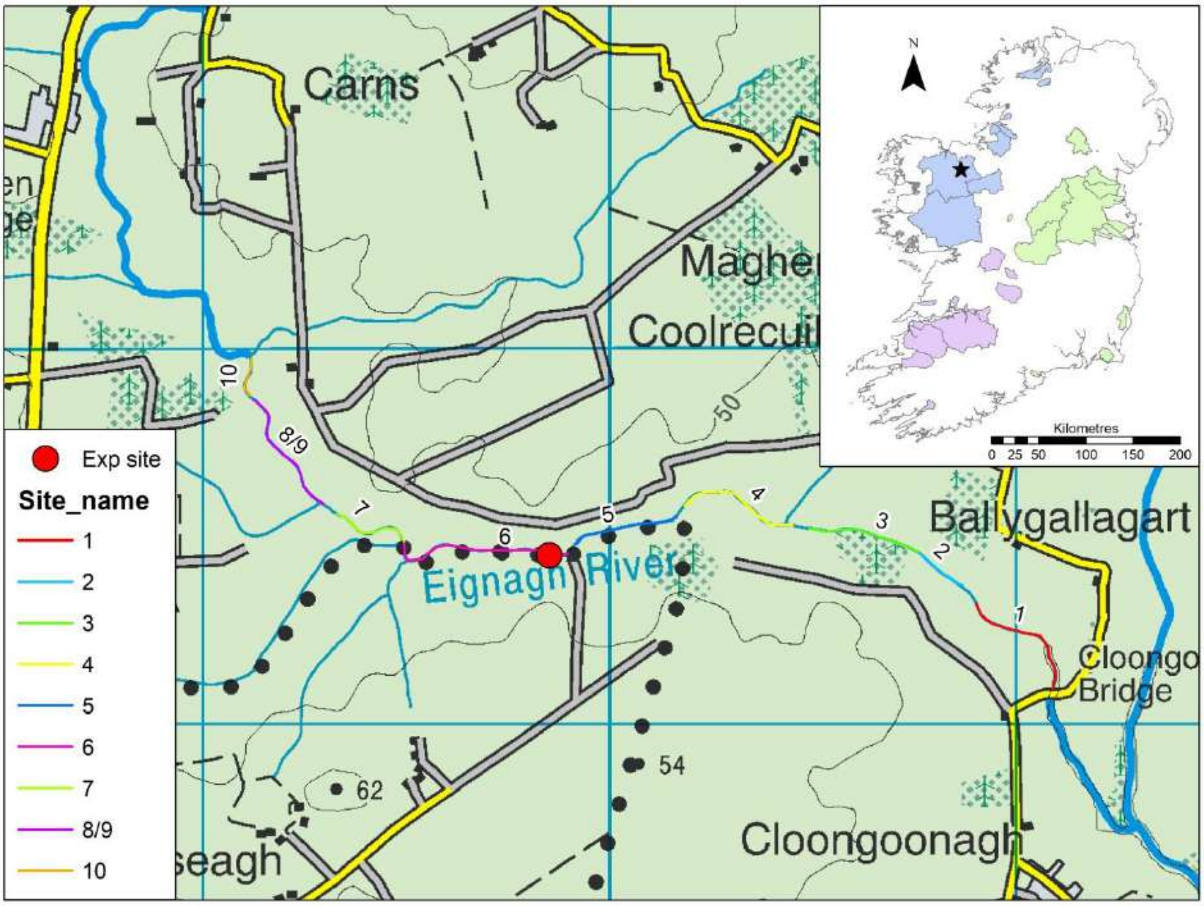


Figure 6.1 The Eignagh River is located in the OPW West region (inset). Map displaying site locations on the Eignagh River.

Following the IFI fish and habitat survey in June 2019, the OPW machines moved on-site to undertake the tree placement works. Paired timbers – suitably cut-down lengths of trees (Figure 6.2) – were drilled to permit pinning into the river (Figure 6.3).

Figure 6.2 EREP Team in 2019 standing beside timber pieces on the bank top, indicating the size of these timber structures.

The timbers were positioned by machine at a relatively shallow angle of approximately 30^0 from the bank facing downstream. Using heavy tracked machinery, the trees were pinned securely in place with 2 x 2m rebar welded to form a T-shape top suitable for pushing into the channel bed with the bucket of the digger (Figure 6.3).

Figure 6.3 Photos of the various steps required to install the timbers.

These features were installed to aid the generation of scour pools for fish. Deflectors function by concentrating flow vertically or horizontally, increasing the speed of flow locally and creating areas of differential scour and deposition. It was important that the timbers were placed securely enough into streambed substrate to make sure they were stable and be at an appropriate height so that they are visible during low flow but overtopped during high flow conditions. This positioning is vital for the structures to work, contributing to new riverine processes within the channel (Figure 6.4).

Figure 6.4 Completed pair of deflectors in the Eignagh River, Co. Mayo, July 2019 during low water levels.

During the long term study on the channel (Chapter 4, page 46), physical measurements such as wetted width, depth and velocity were taken at a series of transects. These measurements were taken at this site prior to the pinning of the deflectors. The EREP team plan to return to this site in 2020 and repeat the physical survey. This will give an indication if the structures positioned in the channel were a success and if they encouraged natural processes i.e. a diversity of depth and velocity measurements, in this riverine system.

A spring 2020 update from the OPW personnel overseeing the Eignagh expressed a satisfaction with the performance of the instream deflectors, indicating that they had remained stable and that they had begun to accumulate fine sediments at the channel margins sheltered by the structures (Figure 6.5). Debris and sediment collection at the margins is positive as it will play a role in stabilising the deflectors. However, the branches should be trimmed before installation, as otherwise the paired deflectors may catch excessive debris within the open channel, as evidenced here.

Figure 6.5 Photo of the deflectors taken in June 2020 during very low water levels.

6.2 River Cor: walkovers & Enhanced Maintenance measures

The River Cor (OPW channel reference C1/1) was programmed for routine maintenance by OPW in 2019. The River Cor is located in the Monaghan Blackwater catchment and hence a synergy with the EU-funded CatchmentCARE project was explored. IFI is a partner in this project and IFI's hydromorphology involvements in it are similar to the broad interests of EREP. The section of channel scheduled for maintenance was 2.4km in length (Figure 6.6).

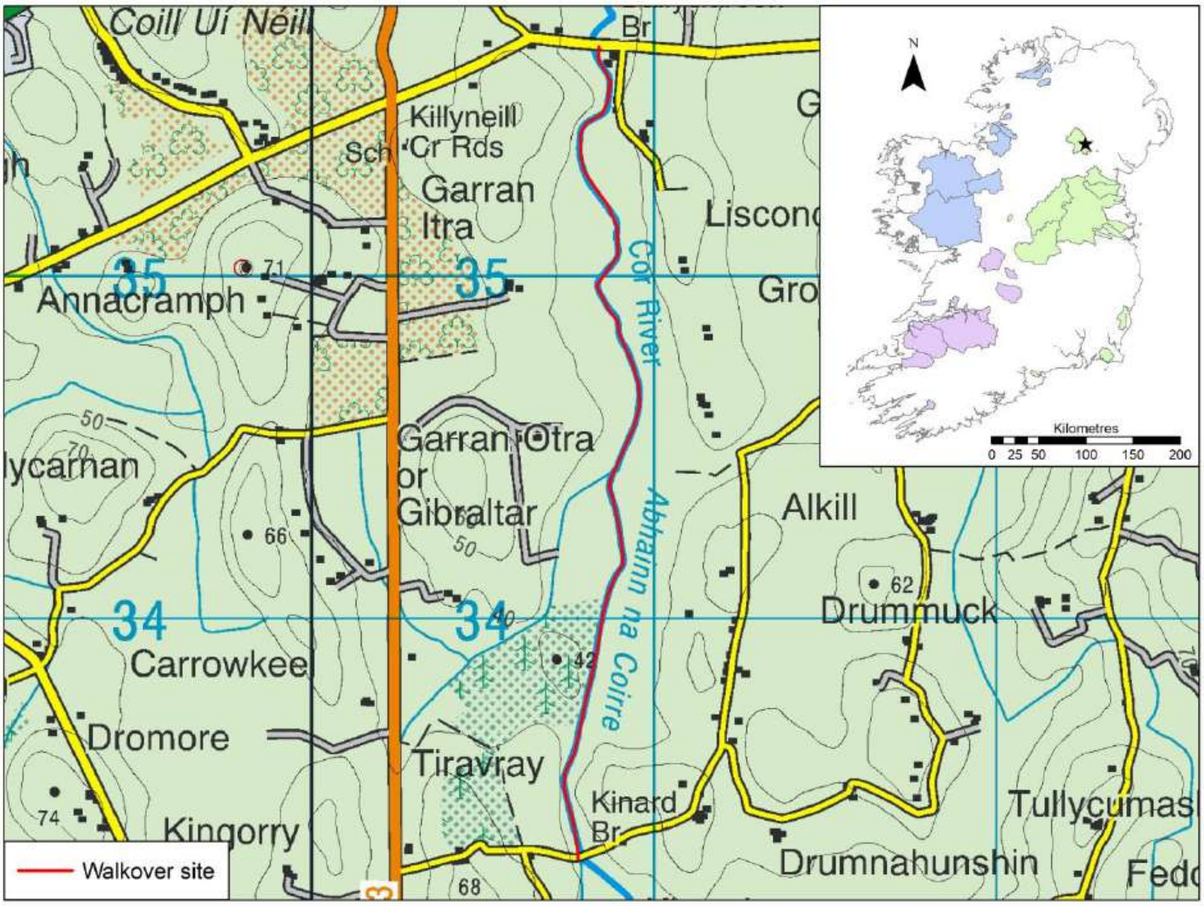


Figure 6.6 The Cor River is located in the OPW East region (inset). The red line indicates the stretch of river assessed during the walkover.

An initial walkover in May 2019, with the attendance of OPW, IFI-EREP and CatchmentCARE project colleagues, examined the entire stretch and advice and recommendations on what works to undertake at various locations were discussed in detail. A programme of measures was agreed between all, and photos and GPS locations taken on site.

The OPW foreman in conjunction with his driver team implemented the Enhanced Maintenance measures on site, and a return visit was made in early August to assess progress. In addition to the Enhanced Maintenance measures, the OPW team had successfully implemented some 'green' engineering bank protection work at a series of sites, using willow material harvested from the maintenance work.

The OPW measures were considered as contributing to enhancing the hydromorphology of the Cor channel. This is one of the aims of the Water Framework Directive i.e. improving the ecological quality of channels – with improvement in hydromorphology as one strategy to achieve this. As such, the aims in maintenance mirrored those of the CatchmentCARE project i.e. ecological improvement of channels, and the CatchmentCARE project had the option of following on the maintenance work with installation of fencing, as a proactive measure to protect banks from cattle poaching, and judicious tree planting to encourage a small corridor of riparian vegetation in the stretch. The fencing was envisaged as providing total livestock exclusion from the channel, necessitating the provision of off-line drinking troughs for livestock. CatchmentCARE planned to take the lead in this aspect of the project and fencing was proposed for both banks along this entire stretch of channel in 2020.

Protect bank slopes (Topic 1)

Soft engineering methods were piloted in this stretch of the Cor which offer an alternative to hard engineering bank protection measures. An example of works completed on the Cor is shown in Figure 6.7. It shows how trimmings of trees, primarily willows, collected during tree management can be used to form bundles which are secured into the bank. This worked well in this channel form and type. Using soft materials complies with WFD and has been used successfully in the past by IFI. The branches catch silt and sediment as its passes during heavy flows, which aid stabilisation of the bank.

Figure 6.7 Soft engineering: willow bundles pinned to bank for reinforcement, which were then covered with a clay sod to incorporate the structure back into the bank.

Topping of berm to form two-stage channel (Topic 7)

Topping of berms allows for a greater area for overflow during higher water levels. An example with before and after pictures on this stretch of the Cor is shown. In this case there was evidence of minor erosion on the right-hand bank, so topping the berm on the left-hand bank increases the cross-sectional area creating a larger area for flows, therefore alleviating the pressure/impact on the right-hand bank. Moreover, allowing the channel to be narrow in low-flow conditions in this small section may create more diversity in flow types and lead to habitat creation. The roots of vegetation in the berm may stay *in situ* stabilising this feature within the river channel.

Figure 6.8 Example of berm management with retention of mature tree cover on the non-working bank.

Re-profile the channel bed (Topic 10)

One example of pool excavation and riffle creation on the Cor is highlighted in Figure 6.9. Over-digging the channel bed in uniform sections of the channel encourages natural riverine processes. For example, deepening one side of the channel allows the river to narrow its main corridor while retaining the cross-sectional area in higher flows. Placing the material collected on the other side of the channel creates low lying berms. Alternatively, another option is to dig pools and strategically placing the substrate downstream, creating riffles. This strategy alters the flow of the river along with providing new habitat for invertebrates and spawning habitat for fish. The deep pools provide resting locations for older fish which were lacking in this channel. This type of instream work adds diversity to flow types and velocities within a drained channel. The channel still maintains its cross-sectional area for flood conveyance, so the aim is simply to alter the shape to promote physical habitat diversity for fish and invertebrates, and also to facilitate natural river processes.

Figure 6.9 Example of pool excavation and riffle creation – before and after experimental digging.

6.3 Conclusion

Eignagh River timber deflectors:

- Where tree management by OPW is necessary, there is potential for value-added measures to be implemented such as the paired timber deflectors to create more diverse instream habitat, which is often lacking in drained channels
- Tree-cutting and instream works windows are not temporally aligned so pre-planning is a necessity in implementing such works
- Further surveys are required to assess the effectiveness of such works on creating more diverse physical habitat

River Cor Enhanced Maintenance measures:

- A synergy was identified between the OPW annual maintenance cycle, IFI-EREP objectives and CatchmentCARE project aims
- Collaboration between all parties resulted in a manageable plan for the stretch to improve hydromorphology, in line with the OPW 10 point environmental guidance
- Fencing for the entire stretch as facilitated by CatchmentCARE will reduce livestock ingress and allow for the establishment of a riparian buffer
- Examples of the Enhanced Maintenance measures highlighted here show the potential for working with the material within the channel to encourage a more process-driven channel form, while retaining the cross-sectional area which is important for flood conveyance in drained channels
- Soft engineering can be used with tree management on site, adhering to temporal windows, to reduce bank erosion where it is presents a problem

Both of these examples show that a proactive approach by OPW to implementing the 10 point environmental guidance has the potential to create more diverse habitat for fish and invertebrates as well as improving channel hydromorphology. Considering the long-term outlook, there are potential gains in various RHAT components including channel form and flow types, bank structure and stability, bank vegetation and possibly substrate condition and instream vegetation (e.g. vegetated berms). These case studies also show the importance of continuing the good working relationship between the OPW regional/environmental sections and IFI staff, and the value of all parties identifying opportunities for river enhancement measures.

7 Survey of OPW gravel traps

The OPW installed a number of gravel/sand traps as part of the engineering design in some of its arterial drainage schemes (Table 7.1, Figure 7.1). Under the WFD, these structures may be adversely impacting on river conditions as they impede natural downstream sediment transport and may also impact on the movement of fish and other biota. The EREP team had discussed these structures with OPW and it was agreed that they would be examined in regard to broad hydromorphological aspects as well as in regard to fish passage issues. OPW commissioned JBA Consulting to undertake a review of the structures in regard to general hydromorphology issues and to make recommendations on mitigation. IFI undertook to examine the fish passage aspects associated with the structures as part of the EREP study. It was considered that a combination of outcomes from the two studies would be informative to OPW in addressing these structures, their current impacts and the impact of removal or other mitigation. The aim of this work package is to examine these traps and their impact on fish passage, as well as a possible role in impeding sediment transport and deposition. This programme is intended to assess the feasibility of their removal or mitigation in order to improve longitudinal connectivity – for upstream fish movement and for downstream sediment transport.

7.1 Progress in 2019

Each of these structures was surveyed using the Level II barrier assessment method employed by IFI – the WFD 111 method developed by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER, 2010) – except for 3 structures or locations which do not present as barriers to fish passage (Table 7.1). This work was done in conjunction with colleagues in IFI's National Barriers Programme. Using the SNIFFER methodology, each structure is assessed for the number of possible routes various species could take in both upstream and downstream directions. Using various criteria each route is assigned a 'barrier passability' score for individual species.

During the 2019-2020 field programme, six of these structures were surveyed to complete the work package (see examples in Figure 7.2-Figure 7.5). Many represent significant issues to fish passage and also to sediment transport, impeding the natural functioning of the river. Further details on each of the structures are presented in a separate report focussed on the SNIFFER results which has been issued to the OPW (Coghlan and King, 2020).

Table 7.1 Details of OPW gravel traps. *Gravel traps which do not present as barriers to fish passage and were therefore not assessed.

Structure Reference	Scheme	Channel Reference	Structure Name	Structure Type	Barrier	Surveyed
ST5	Brosna	C3(1)	Cadamstown Upper	Weir	Yes	2017
ST6	Brosna	C3(1)	Cadamstown	Weir/ Sluice	Yes	2020
ST7	Brosna	C8(19)	Clonaslee	Weir/ Sluice	Yes	2017
ST8	Duff	C1	Duff	Weir	Yes	2019
ST9	Mulkear Cappamore	C1	Blackboys Br	Weir	Yes	2017
ST10*	Mulkear Cappamore	C1	Cappamore	Weir	No	n/a
ST11*	Maigue	C1/31/24	Morning Star	Channel Section	No	n/a
ST12	Maigue	C1/34	Loobagh River	Weir	Yes	2020
ST13	Nenagh	C1/9	Ollatrim	Weir	Yes	2020
ST14	Nenagh	C1	Nenagh River	Drop Weir	Yes	2019
ST15	Nenagh	C1/9	Bessborough	Drop Weir	Yes	2019
ST16*	Nenagh	C1/14	Nenagh (Dolla)	Channel Section	No	n/a

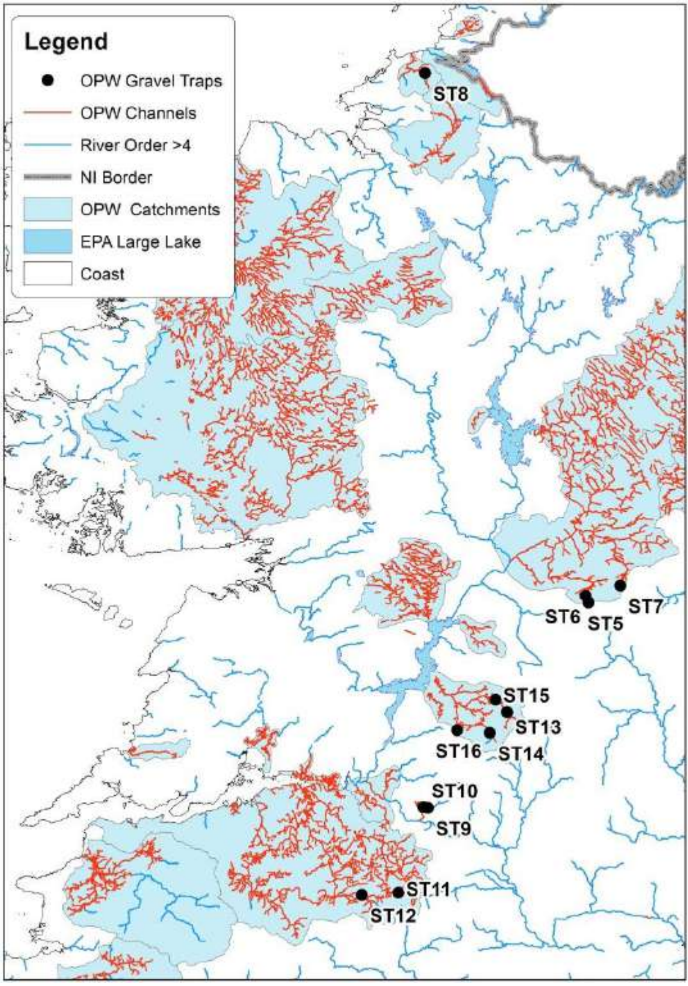


Figure 7.1 Locations of OPW Gravel Traps.

Figure 7.2 Gravel trap on the Largydonnell Stream, Duff catchment (ST8).

Figure 7.3 Gravel trap on the River Loobagh, Maigue Catchment (ST12).

Figure 7.4 Gravel trap on the Kilcormac Silver, Brosna catchment (ST6).

Figure 7.5 Drone image of the gravel trap on the Kilcormac Silver, Brosna catchment (ST6).

Figure 7.6 Gravel trap on the Ollatrim River, Nenagh Catchment (ST13).

8 Synergies with other IFI studies

Many of IFI's fish studies within specific projects and programmes are inevitably linked. As outlined in the annual report of the EREP for 2018, there are currently three programmes conducted by IFI which have a close synergy and linkages to the overall EREP umbrella and to environmental information of relevance to OPW:

- IFI monitors the status of fish species designated under the EU Habitats Directive and reports to the EU on a 6-year basis on Atlantic salmon and on lamprey species. Catchment-wide sampling is undertaken on a scaled basis for larval lamprey and many of the Special Areas of Conservation or SACs designated for lamprey will be examined. These include a number of OPW catchments such as the Moy, Corrib, Boyne and Bonet and data on lamprey status and location compiled in these studies will be made available digitally to the OPW for adding to its GIS layer of environmental items. Similarly, IFI undertakes catchment-wide surveys on juvenile salmon status and this programme covers a wide range of catchments, including the majority of major OPW schemes not designated as SACs e.g. the Glyde-Dee, Maigue and Deel.

- The National Barriers Programme (2018-2021) is funded by the Department of Housing, Planning and Local Government. IFI is tasked with a series of actions by 2021 including development of protocols for barrier assessment, data collection on barriers in catchments, development of mitigation proposals and prioritisation processes for addressing barrier issues in the third cycle of the WFD. The barrier surveying will be undertaken on a large scale, as IFI resources permit. Information gleaned in EREP surveying in OPW catchments will be available to the OPW. Likewise, the information compiled in specific barrier surveys in particular OPW drainage schemes within the EREP study (using the same survey protocol) will merge into the National Barriers Programme database of structures. During 2019, the EREP team worked with National Barriers colleagues in completing the SNIFFER barrier assessments for fish passage on the series of OPW gravel traps (see Chapter 7).

- The INTERREG CatchmentCARE project (2017-2022) is tasked with examining and bringing forward measures to improve the ecological quality of waters in three cross-border catchments, including the Blackwater (Monaghan/Ulster). IFI is a partner in the project and has assessed channels and strategies to improve their hydromorphology, and thereby improve their ecological status under WFD. Both the OPW (RoI) and Department for Infrastructure (DFI) [formerly Rivers Agency (NI)] are vital components in this project within the Blackwater, given that the catchment is arterially drained. IFI personnel in the CatchmentCARE project are working with the EREP team and with the OPW in regard to examining channels and appropriate measures within the Monaghan Blackwater CDS – the aspirations of the CatchmentCARE project mirroring those of EREP. During 2019, a walkover on a 2 km section of the River Corr/Clontibret with OPW, EREP and CatchmentCARE was undertaken (see Section 6.2). This section of channel was scheduled for maintenance in 2019. The shared walkover identified a range of strategies for habitat retention, for experimental options and for 'green engineering' that were consistent with OPW's 10-point guidance on environmental maintenance and fitted under the broad umbrella of EREP. The scope for value-added, in terms of fencing that could be installed and funded under the CatchmentCARE project was also agreed. Similar opportunities will be explored in the Blackwater during the 2020-2022 period of the CatchmentCARE project.

9 Going forward – development of EREP in 2020 and beyond

The EREP has undergone various revisions, changes of emphasis and degrees of reduction of staffing support since its inception in 2008. This is inevitable in a dynamic project involving two agencies with different, sometimes contrasting, statutory obligations.

A consistent underlying thread has been the shared view that both OPW and IFI benefit from constructive engagement and from combined project work dealing with the river corridor and its management. The realignment of project elements in 2017, with a focus on scientific surveys in OPW catchments and development of management strategies to emerge from the findings was considered successful by both agencies in an initial review of the 2017 outputs. This contributed to the signing of a 5-year agreement by OPW and IFI in 2018, undertaking to continue with applied scientific studies and experimental investigations in OPW-managed catchments in a context guided by key EU Directives – the Water Framework Directive, the Habitats Directive and the Floods Directive.

The 5-year commitment by OPW and IFI allows for planning in regard to agreed studies and investigations in a scenario where resources of time and people power can lead to positive outcomes. The WFD and its emphasis on (a) ecological quality and on (b) hydromorphology underpin activities with the EREP.

a) Ecological Quality is summarised in the WFD by the Ecological Quality Ratio (EQR) which is categorised in five scores – High, Good, Moderate, Poor and Bad. The requirement of the Directive is for waters to achieve at least Good status in regard to the biological elements such as the fish community

b) The hydromorphology element relates to the quantities of water, the condition of the instream and riparian zones and the lateral and longitudinal connectivity of the channel

In the context of the agreed 5-year programme the EREP project team in IFI has developed an outline plan of work to cover the period of 2019 – 2022. The structure includes continued knowledge accumulation and sharing of fish and habitat data in a WFD-focussed framework, with a catchment-wide survey planned and expedited in the Deel in 2019 (see Chapter 2). Further such catchment-wide fish and habitat surveys are planned in the lifetime of the current 5-year EREP study (Table 9.1).

In 2017, IFI was tasked by the Department of Housing, Planning and Local Government with producing a series of deliverables in regard to barriers within rivers impeding fish migration, in the context of WFD and Programmes of Measures. The barriers survey on the Inny (2017-18) and the Deel (2019) in EREP generated data that can feed directly into this national endeavour, as will any further barrier work within the EREP. Similarly, survey work undertaken as part of the IFI's National Barriers Programme will be available to feed across to the EREP. Another potentially valuable contribution of EREP here is the potential for OPW to identify practical and reproducible strategies to address certain types of barrier issues within its drainage schemes e.g. bridge floors set too high relative to the immediate downstream river bed, causing scour. The National Barriers Programme will develop measures to address structures and issues impacting on fish migration and OPW would be an important contributor here.

OPW has expressed its satisfaction with the proposal to continue to develop long-term data sets associated with fish and habitat surveys undertaken in shared OPW-fisheries investigations. Some of these date back to the early 1980s and there is a substantial platform of valuable surveys and discrete time-series dating from the initial Environmental Drainage Maintenance (EDM) studies, dating from 1990-2007, and from the EREP investigations commencing in 2008. Such extended-term studies have already proven to be useful in providing information on the response and status of crayfish and larval lamprey to channel maintenance activities. The scientific literature commonly flags and laments the paucity of long-term monitoring of recovery in channel enhancement or impact studies and the OPW recognises the potential for EREP to contribute here and is encouraging of this potential. The long-term studies permit a revisiting of channels where investigations were undertaken on specific topics or strategies with the EDM study (1990-2007) as well as permitting a review of both Capital Works and of Enhanced Maintenance sites within the EREP (2008-2015). The reviews undertaken in 2019 – of Capital Works on the Enfield Blackwater (Chapter 3) and of Enhanced Maintenance on the Eignagh (Chapter 4) were highly informative. An on-going programme of such reviews is scheduled for the remaining years of the current 2018-2022 EREP study (Table 9.1).

These 'review studies' have also enabled a detailed examination of some purely 'engineering' data collected e.g. longitudinal profiles and cross-sectional levelling surveys, compiled by the IFI teams over many years. The initial surveys formed part of an initial assessment and monitoring of pre- and post- works undertaken by OPW. The long-term monitoring of these sites provides an insight on the 'longevity' of various physical modifications of the cross- and longitudinal-sections of channels and of the impact of these modifications on dimensional measurements of channel form. The review data presented in this report (Chapters 3, 4, 5) is considered very pertinent and highly informative in identifying the appropriateness of some of these measures.

The form EREP will take, going forward, is likely to change from year to year with changing pressures and priorities on the two organisations. Thus, OPW continues to identify the relevance of monitoring on crayfish and larval lamprey, with the potential for channel maintenance to impact adversely on these Annex II species groups and to add to the shared published research already produced by EDM and EREP (King *et al.,* 2008; King *et al.,* 2015). There is a concurrence that there are major elements of shared interest between OPW and IFI and these can continue to be explored and investigated under an EREP umbrella (Table 9.1).

In compiling this annual report for the EREP covering the 2019 period one is very conscious of the current climate where normal working conditions and scenarios, for outdoor and indoor work, are heavily circumscribed if not completely unavailable. In these circumstances it is impossible at this stage to identify what works OPW may be able to undertake in 2020 within its normal channel maintenance remit. Likewise, it is not possible for IFI to identify what EREP survey elements, scheduled for 2020, may be feasible. Given the current scenario, as of mid-May 2020, it is equally impossible to identify what shared actions may be undertaken in the present year. Meetings at all three of the OPW's regional head offices in early 2020, involving relevant OPW and IFI personnel proved very positive. There was an identification of the clear linkage between waterbody status (as per WFD), hydromorphology scoring (RHAT-scores) and scope for channel maintenance practices of OPW to function in a manner that could impact positively on RHAT. A key to progressing this linkage is a substantially greater implementation of Topic 10 of the OPW's environmental guidance, involving manipulation of the channel cross- and long-section in appropriate locations. This had been previously identified by OPW and IFI as an issue requiring more attention (King *et al.,* 2011). To help advance this issue, the meetings identified the desirability of designating approximately 2 channels per OPW region where a detailed walkover would be undertaken in 2020. Each walkover would identify specific locations on each channel where measures could be undertaken and specify what these measures may be. This would not generate a detailed 'design document' but an annotated map of locations and options could be compiled. OPW drivers have demonstrated their capacity to assimilate and put into practise the various strategies outlined in Topic 10 and the walkovers would be intended as an impetus and encouragement to foremen and drivers to continue and expand the level of implementation of Topic 10.

Table 9.1 Five year plan for the Environmental River Enhancement Programme

ACTION	2018	2019	2020	2021	2022
FPI Study (Fish,Habitat,Barriers)	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	Brosna I: (Source - Clara)
Long term report studies I: Capital Works		Enfield Blackwater (Boyne) (2009 - 2010)	Robe at Sheepwash Bridge (Corrib - Mask) (2008 - 2010)	Dee at Hem Bridge (Glyde - Dee) (2008 - 2010)	Morningstar (Maigue) (2009 - 2010)
Long term report studies II: Maintenance impacts	Attymass (Moy)	Cloonlavis (Moy)	Deel (1998 - 2000)	Lung (2001 - 2007)	Moynalty (1996 - 2001)
	Camoge (Maigue)	Eignagh (Moy)			
Feasibility studies for river enhancement		Boyne tributaries (x4)			
Specific Investigations					
Climate change / thermal studies in drained chennels	Brosna tribs	Tullamore River / Tulamore Silver	To Be Selected		
	(Tree cover)	Sparganium Tall Emergent Vegetation Year 1	Sparganium Tall Emergent Vegetation Year 2	Water Celery/Cress vegetation Year 1	Water Celery/Cress vegetation Year 2
Tree mgmt./ trees and riparian cover	Attymass; Atherlow (Control)	Deel desk study; Eignagh	Kells BW desk study	Lung desk study	Brosna I (Source - Clara) : desk study
Impact of channel modifications (long X; cross X) and relevence of Topic 10 in 10-step guidence	Camoge (Maigue)	Cloonlavis; Cloonshire; Tullamore Silver; Enfield Blackwater	Clodaigh; Eignagh		Moynalty (1996 - 2001)
Crayfish studies	FPI Inny	FPI; Tullamore River repeat survey	FPI; Robe repeat survey	FPI	FPI
Lamprey studies	FPI Inny	FPI	FPI	FPI	FPI
Synergies with other studies					
Habitats Directive (Lamprey) -	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	Brosna I: (Source - Clara)
IFI National Barrier Programme -	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	
INTERREG Catchment CARE -		Monaghan - Blackwater	Monaghan - Blackwater	Monaghan - Blackwater	Monaghan - Blackwater

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