River Boyne WFD III Barrier Assessment

Obstacles to Fish Passage and Mitigation Options

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NATIONAL BARRIERS PROGRAMME

Iascach Intíre Éireann
Inland Fisheries Ireland

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Table of Contents

Summary

The River Boyne has a long history of anthropogenic use and its associated river modifications including weirs, sluices, and diversion channels. Now, many of the industrial and historical uses requiring this infrastructure are defunct, but the instream structures remain. Consequentially, the lower 24 km of the main channel of the River Boyne, from Navan to Drogheda, contains 14 historic weirs, almost all of which severely restrict passage for multiple fish species. These large structures prevent diadromous species such Atlantic salmon and European eel from reaching and/or utilising substantial swathes of the River Boyne habitat.

Although the river is subject to various anthropogenic pressures, the Boyne still supports several resident and migratory fish species and retains considerable ecological potential. Unfortunately, much of the river downstream of Navan is only realising a Water Framework Directive (WFD) status of "Moderate" and is therefore failing the WFD requirement of achieving at least "Good" status. The River Boyne is significantly fragmented. The lack of longitudinal connectivity impacts on its WFD status and its ecological health. Much of the Boyne, its tributaries, and its riparian habitat have been designated as a Special Area of Conservation (SAC) and a Special Protection Area (SPA) under the Habitats Directive. Conservation objectives of the SAC require the restoration of access to lower order streams for river lamprey and Atlantic salmon. To achieve a favourable conservation status for the SPA, the river functions necessary for habitat maintenance must be operational. Currently the habitat forming processes such as sediment transport are constrained by the instream structures.

The 14 major weirs on the lower Boyne were surveyed predominantly from July to September 2021 using the WFD III or SNIFFER barrier assessment protocol. The exception, Blackcastle Weir, was assessed in January 2021. Individually, the barriers were generally found to be major impediments to fish passage. In a sequence, the barriers present an even greater challenge for species movement, which becomes cumulatively harder as biota move through the system. Considered together as a complex, they substantially block migratory fish species from accessing most of the river and degrade/impound the habitat they need to complete their life cycles.

Interventions are now required to improve the Boyne's fish community. The easing of fish passage at the structures outlined in this report will help migratory species such as salmon, sea trout, eel, and lamprey spp. to freely utilize upstream environments. Consequently, this will improve the fish community status as required under the WFD and return iconic fish species to places where they have become absent. Mitigation would provide additional benefits in the form of improved stocks for upstream anglers, increased resilience to climate change, and the preservation of a salmon population intrinsically linked to our cultural heritage.

Background

A range of structures in rivers can interfere with fish migration. These structures include bridge floors, culverts, sluices, and weirs. The structures may span the full width of the channel or a portion of the channel. Structures that span the full width are the most likely to provide difficulties for fish movement. Some fish species, known as diadromous species, spend part of their life cycle at sea and part in freshwater. It is vital that these species are able to migrate between freshwater and marine habitats to complete their life cycle. The migratory fish species in Ireland– Atlantic salmon, sea trout, sea lamprey, river lamprey, twaite shad, allis shad, and the European eel, have been native to the island since the last Ice Age. A range of other fish species, such as pike, brown trout, and bream, live entirely in freshwater but are known to travel extensively for feeding or spawning. Impediments to passage can lead to fish suffering from physiological stress, predation, loss of energy, and physical damage. Any delays to fish migrations may have negative consequences for their reproductive capacity and could lead to a decline in population.

Relevant legislation

Several of the fish species noted above are listed in Annex II of the European Union (EU) Habitats Directive (92 / 43 / EEC), including Atlantic salmon, lamprey spp., and shad *sp*. This legislation obligates Ireland to restore or maintain, to a favourable status, both the habitats and populations of wild flora and fauna. Ireland has designated Special Areas of Conservation (SACs) on several of our large river systems where the conservation status of these species is of particular concern.

The EU Biodiversity Strategy for 2030 exceeds the aims of the existing Habitats Directive. It addresses the need for increased resilience to threats such as climate change and contains a programme of measures to reverse biodiversity loss. A primary objective is the restoration of continuity to at least 25,000 km of rivers within the EU by 2030. The Nature Restoration Law, a key element of the strategy, was proposed in June 2022 by the European Commission. Article 7 of this regulation will require the identification and removal of barriers to lateral and longitudinal connectivity in surface waters. Within two years of the new regulation coming into force, member states will be expected to submit National Restoration Plans to the Commission describing how targets are being delivered. Continual monitoring and progress reports will also be expected.

The Water Framework Directive (WFD) (2000/60/EC) requires Ireland to protect and improve water quality, with the aim of achieving "Good" ecological status by 2027. Multiple contributing factors, known as quality elements, are considered when assessing the ecological status of a waterbody. One such quality element is fish species composition. This is assessed by comparing the current fish community of a waterbody to the predicted fish community under favourable conditions. Another important quality element is 'hydromorphology'. This term combines the quantity and dynamics of water flow (hydrology) with the quality of the physical habitat (morphology). A third component of hydromorphology is that of 'continuity' or 'connectivity'. This refers to the undisturbed movement of water flow, aquatic wildlife, and sediment within the river.

The EU Eel Regulation (COUNCIL REGULATION (EC) No. 1100/2007) is concerned with the recovery of European eel stocks. The species is critically endangered under The International Union for Conservation of Nature (IUCN) Red List. One of the primary objectives of the regulation is to facilitate the upstream migration of juvenile (glass) eels and the downstream migration of mature (silver) eels by improving river corridor connectivity. As the species is catadromous, adults must migrate towards the Sargasso Sea to spawn. A recent review of the Eel Regulation (European Commission, 2020) recommended an increased focus on making rivers more passable for the species.

River Connectivity and Habitat Fragmentation

In the main, the river systems of Europe have been altered for the economically important purposes of supplying water, generating power, navigation, and flood mitigation. However, there has been little consideration of the related environmental consequences. River ecosystems are shaped by, and dependent on, the natural movement of water, sediments, nutrients, and stream biota. Excessive alteration of the magnitudes, duration, frequency, and timing of flows can substantially impair the ecological productivity of these systems. Infrastructure including dams, levees, diversions, and channelization works, reduce the dynamism and diverse characteristics of river systems leading to comparatively fragmented, static, and simplified habitats. Biota must navigate through these homogenised habitats to reach isolated patches of river that are still able to support their life cycle. The discontinuity in habitat quality can diminish stream biota resilience to negative events by limiting species' abundance and dispersal. This has implications for the population structure and species' renewal after a disturbance (Mueller *et al.*, 2011).

Artificial structures can also lead to the fragmentation of a river's thermal regime in multiple ways. Altered from its lotic state, impounded water performs thermally like a lake rather than a river. This creates a segment of the waterbody with a temperature different to that of the wider reach. Native cold-water species must traverse this thermal barrier to access the upstream or downstream habitat. Secondly, discharges from such static environments can differ dramatically in temperature from the downstream environment into which they flow. Ectotherms, such as fish, rely on the habitat around them to regulate their own body temperature. Sudden changes in their environment can have negative impacts. Discharges, in particular from thermally stratified reservoirs, can be detrimental to downstream aquatic assemblages (Olden and Naiman, 2010). Lastly, the lowered volume of water within a channel, due to a stemmed flow or abstraction, is more susceptible to changes in atmospheric temperature than rivers at full capacity. Alterations to the natural thermal regimes of rivers can render waterbodies more susceptible to the impacts of climate change (Woodward et al., 2010), influence life cycle cues (Olden and Naiman, 2010), and favour invasive species with a wider thermal tolerance.

Connectivity acts on one temporal and three spatial dimensions. The temporal dimension is the continuity of interactions, usually in a seasonal pattern, that structure a habitat. The spatial dimensions include: longitudinal connectivity from headwaters to confluences and the sea, lateral connectivity from the main channel to floodplains, and vertical connectivity between the riverbed and groundwater in the hyporheic zone. The importance of each dimension changes along the river course and has led to the development of complimentary concepts in landscape ecology:

- Hydrological connectivity supports the passive downstream transport of material and energy, but also enables a multidimensional dispersal of organisms.
- Ecological connectivity emphasises the connection between different areas of habitat. This is particularly important in linear river ecosystems, where certain species and life stages require diverse habitats along the river continuum to complete their life cycle.

Loss of ecological connectivity can be described as a consequence of habitat reduction, in which large, continuous habitat is broken up into many smaller fragments. The few remnants of quality habitat are separated by an anthropogenically modified matrix of different land use types. The presence of artificial barriers along the river continuum creates a challenge for species movement, which becomes cumulatively harder as a species move through the system. Moreover, the sub-optimal habitat between better areas means that biota must expend more energy moving from location to location. Habitat loss and the associated fragmentation has a dual effect. It disrupts the spatial patterning of resource availability and also limits the carrying capacity at each patch i.e. dispersed habitat is harder to reach and can support less organisms. Remediation efforts to improve connectivity should, therefore, take a complimentary approach that aims to mitigate barriers to improve passage and also increase overall habitat quality.

Assessing structures for passability – the WFD111 method

Structures that interfere with continuity can be considered barriers. Regarding fish migration, barriers can present a problem under both the Habitats Directive and the Water Framework Directive. In the course of implementing the WFD, EU member states have developed a range of sampling strategies for quality elements. As part of this process, a barrier assessment was developed by SNIFFER (Scotland and Northern Ireland Forum for Environmental Research). This process is known as the WFD 111 method. It has been used extensively in Northern Ireland and is currently used by Inland Fisheries Ireland to examine structures where some form of remedial work (partial removal, full removal, or modification, etc.) is proposed.

The WFD 111 barrier assessment methodology examines the structure and identifies the number of potential routes that fish species could use to surpass the barrier (travelling upstream or downstream). Each possible route is referred to as a 'transversal section' (TS). A series of criteria are then assessed at each transversal. The criteria include:

- water velocities
- depth of water over the structure's surface
- hydraulic head height
- length of structure's slope
- Slope (hydraulic head / length X 100)
- presence/absence of a plunge pool
- flow type.

A flow meter and engineering level are used in collecting the survey data. The field data gathered from all transversal sections is referenced against tabled values for each fish species present in the catchment. A 'barrier passability' score for individual fish species or life stage is then calculated (Figure 1). Upstream migrants include Atlantic salmon, brown trout, shad, cyprinids, pike, river lamprey, sea lamprey, and juvenile eels. Downstream migrants include salmon smolts, juvenile lamprey, and adult eels. All values generated are specific to the date of survey and the river conditions at the time.

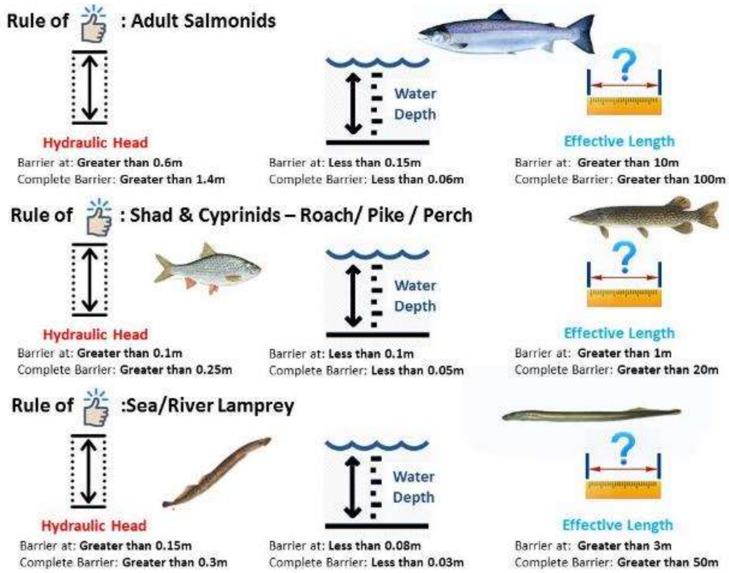


Figure 1. Guideline metrics for assessing barrier risk.

Passability scoring.

There are four scores devised for the WFD 111 assessment (SNIFFER, 2010):

- **Complete barrier (value = 0.0):** Impassable, complete obstacle for the target species/life-stage
- **Partial high impact barrier (value = 0.3):** The structure represents a significant impediment to the target species/life-stage but some of the population (e.g. < one third) will pass eventually
- **Partial low impact barrier (value = 0.6):** The structure represents a significant impediment to the target species/life-stage but most of the population (e.g. > two thirds) will pass eventually
- **Passable barrier (value 1.0):** No obstacle.

The River Boyne

The River Boyne, *Abhainn na Bóinne*, has a main stem length of 113 km, while the catchment encompasses an estimated 2,694 km^2. A low average gradient (1.24m/km) from the source in Kildare to the sea in Drogheda is characteristic of the catchment. The northern part of the catchment is drained by the Kells Blackwater, while the southern half is drained by the Boyne itself, before the two merge at Navan. The main tributaries of the Boyne include the Athboy, Boycetown, Clady, Deel, Longwood, Blackwater, Mattock, Skane, Stonyford, and Yellow.

Historically, the instream structures on the Boyne from Drogheda to Navan (the stetch of river considered in this report) were often associated with mills, transport, and fisheries. The historic 6" and 25" OSi maps regularly display fish weirs (Oldbridge, Dowth, Newgrange, Blackcastle Demesne), corn or flour mills (Dowth, Slane, Dollardstown, Stackallan, Dunmoe, and Blackcastle), and canals. Some locations have had an instream structure present since medieval times. The Cistercian abbey of Mellifont, founded in the 12th century, owned the fisheries of the Boyne for a considerable stretch of the river (Went, 1953). In 1358, the Abbot, Reginal Lynagh, won a legal action regarding the Abbey's fishing weirs at Rosnaree. Knowth, and Stalleen. However, in 1366, he was indicted for erecting a weir at Oldbridge. The weir was ordered to be partially removed, and the Abbott committed to gaol. Three years later his successor was charged for a similar offense. Just before the dissolution of the monasteries, a statute from the Parliament of Dublin ordered that "All weares…and other obstacles in the River Boyne…to the traffic of boats…and to the great hurt of the "salmon fry"… be broken and removed" (Brewer and Bullen, 1867). By 1541, the Mellifont abbey and its fisheries had been leased to Lawrence Townley of Dublin (Went, 1953). As the industries utilising the river have developed over the centuries, instream structures have accumulated. However, many of these structures are now obsolete.

Culturally, the River Boyne is host to one of Ireland's most prominent legends. The Salmon of Knowledge, *An Bradán Feasa*, was fished from the Boyne by the poet Finegas, only to have its flesh first tasted by Fionn Mac Cumhaill. Fionn became wiser than all other men and went on to become a great warrior and leader of the Fianna. Physical remnants of our heritage are also common to the Boyne. The river is surrounded by sites of archaeological note such as the prehistoric burial chambers of Newgrange.

The river was subject to extensive arterial drainage in the late 20th century by the Office of Public Works (OPW), primarily to improve the surrounding land for agriculture. This substantially altered the character of the river. The major arterial drainage scheme on the Boyne lasted from 1969 to 1986 (OPW, 2022). Due to obligations under the 1945 Arterial Drainage Act, the OPW has continued to maintain arterial drainage channels in the catchment. Despite the drainage scheme, large portions of land neighbouring the Boyne from Slane to Drogheda have a high probability of fluvial flooding with an Annual Exceedance Probability (AEP) of 10%. This percentage refers to a 1 in 10 chance that a high probability fluvial flood event will occur, or be exceeded, within any given year (OPW, 2019).

The WFD River Waterbody Status (2013-2018) within the Boyne catchment varies predominantly between "Moderate" and "Good" (EPA, 2019). However, towards the east of the catchment larger areas of "Poor" quality appear. Between Cycle 2 and Cycle 3, the number of waterbodies in the catchment achieving a "High", "Good", or "Bad" status decreased, while the number of "Moderate" and "Poor" waterbodies increased. In the Boyne catchment, 75 of the 116 river waterbodies (65%) are at risk of failing to meet WFD objectives (EPA, 2021).

Much of the River Boyne, its tributaries, and its riparian habitat are within the River Boyne and River Blackwater Special Area of Conservation (SAC), of which River lamprey, *Lampetra fluviatilis*, and Atlantic salmon, *Salmo salar*, are among the qualifying interests. Both are Annex II listed species in the EU Habitats Directive. The headwaters and tributaries of the Boyne are used as spawning grounds for Atlantic salmon, while River Lamprey are known to be present in the lower reaches (NPWS, 2014). Lamprey *spp*. were also recorded in the Athboy tributary during a 2016 WFD survey and in the Boyne main stem, upstream of the Kells Blackwater convergence, in a 2009 WFD survey (IFI, 2022). Conservation objectives of the SAC include restoring access for river lamprey to all water courses down to first order streams and ensuring accessibility to 100% of the river channels down to second order for Atlantic salmon (NPWS, 2021).

The majority of the river channel has also been designated a Special Protection Area (SPA) under the EU Birds Directive. The primary qualifying interest is the kingfisher, *Alcedo atthis*. This species is listed on Annex I of the EU Birds Directive. The River Boyne and River Blackwater SPA (site code 004232) is particularly influential as it supports a kingfisher population of national importance. Crucial to the survival of the species is the proper functioning and conservation of its habitat. Favourable conservation status of the habitat is not possible without “the functions which are necessary for its long-term maintenance” (NPWS, 2022). Blockades in the Boyne prevent many of the habitat forming processes of the river and the functioning of the waterbody itself. Additionally, insufficient fish passage could negatively impact food availability for the species. A 2010 survey found 19 kingfisher pairs within the River Boyne and River Blackwater SPA, a reduction from the 20 to 22 pairs recorded in a 2008 survey (NPWS, 2010). Other bird species present in the SPA include the mute swan, teal, mallard, cormorant, grey heron, moorhen, snipe, and sand martin (NPWS, 2010).

The Boyne catchment has several urban centres including Drogheda, Navan, Trim, Kells, Athboy, Edenderry and Kinnegad. The local population, in addition to tourists, utilise the river for amenities such as angling, kayaking, and bathing. The Boyne also provides drinking water for public supply. Landuse in the catchment is primarily pastural agriculture, with additional areas used as non-irrigated arable land.

Nutrient pollution, such as excess phosphorus caused by run-off from farmyards or poorly drained soils, is the primary issue for rivers in the Boyne catchment (EPA, 2021). Additional issues include morphological impacts, organic pollution, hydrological impacts, and sediment (such as the sediment created by animals accessing the river). The main pressure contributing to issues, and impacting the largest number of waterbodies, is agriculture (EPA, 2021). Other pressures are hydromorphology, domestic wastewater, peat, urban wastewater, urban run-off, and industry. A comparison of Cycle 2 and Cycle 3 showed that agriculture has increased as a pressure, impacting an additional 17 waterbodies in Cycle 3. In contrast, urban wastewater, domestic wastewater, peat, and industry have had a reduced impact from Cycle 2 to Cycle 3.

WFD 111 Barrier Assessment Results:

Fourteen major barriers were surveyed on the main channel of the River Boyne between January 2019 and September 2021 (Figure 2).

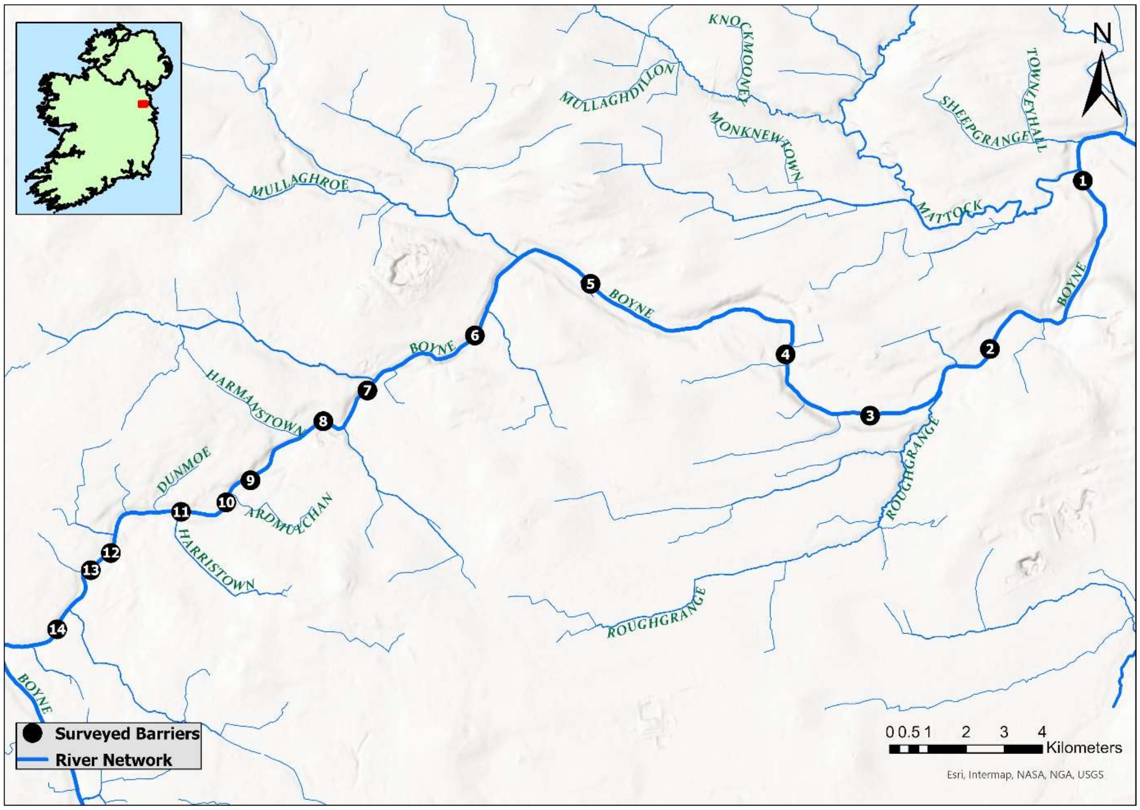


Figure 2. Location of WFD 111 barrier surveys in the Boyne catchment, 2019-2021.

1. Oldbridge Weir

River: Boyne	Survey Date: 31/08/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, J O'Connor
River Basin District: ERBD	Grid ref: 703843,775538
River Water Body: 07_1716_282	Name of Structure: Oldbridge Weir
Owner: Oldbridge Anglers-Canal	IFI Analyst: R Donovan, A O'Connell

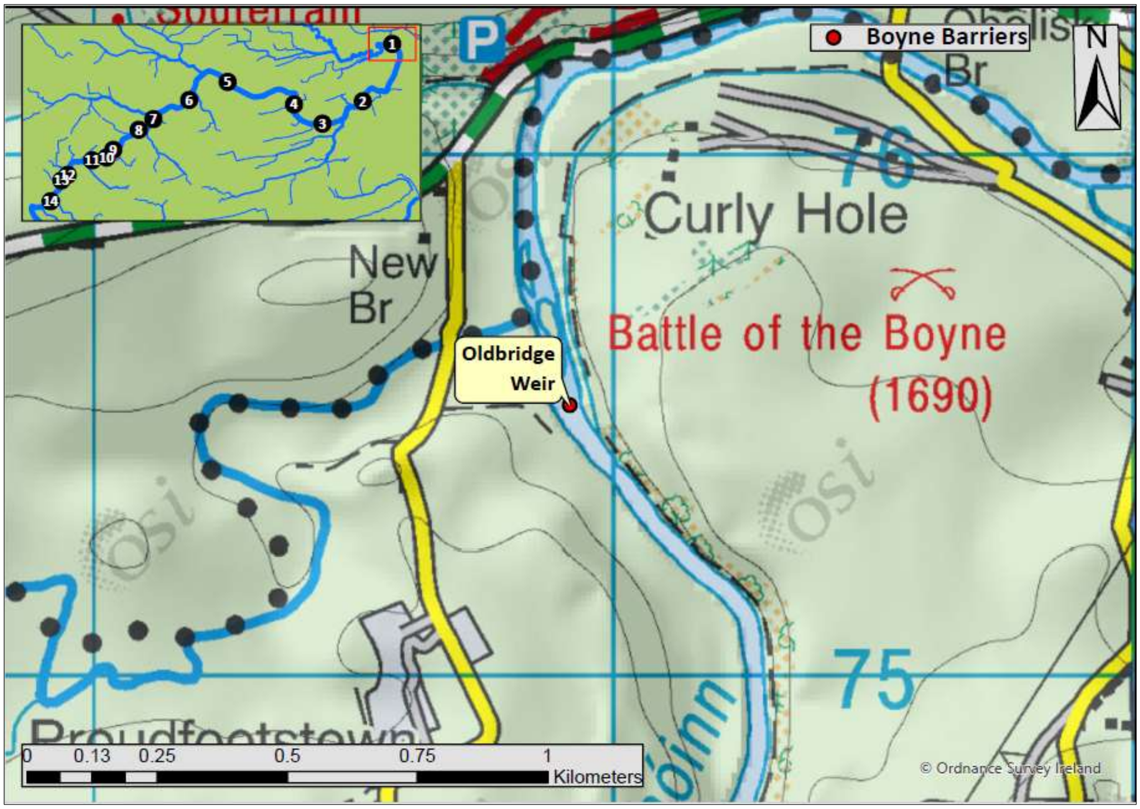


Figure 3. The location of Oldbridge Weir in Co. Meath, approximately 4 km west of Drogheda, Co. Louth.

Oldbridge Weir is located on the main stem of the River Boyne, an estimated 4 km west of Drogheda, Co. Louth. It marks the EPA high water mark and rests on the border between the townlands of Oldbridge and Proudfootstown. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in an area of river with a "Good" status. A weir is visible on the historic 6" OSi maps (1829-1841), suggesting that a structure has existed in this location since at least the early 19th century (Figure 4).

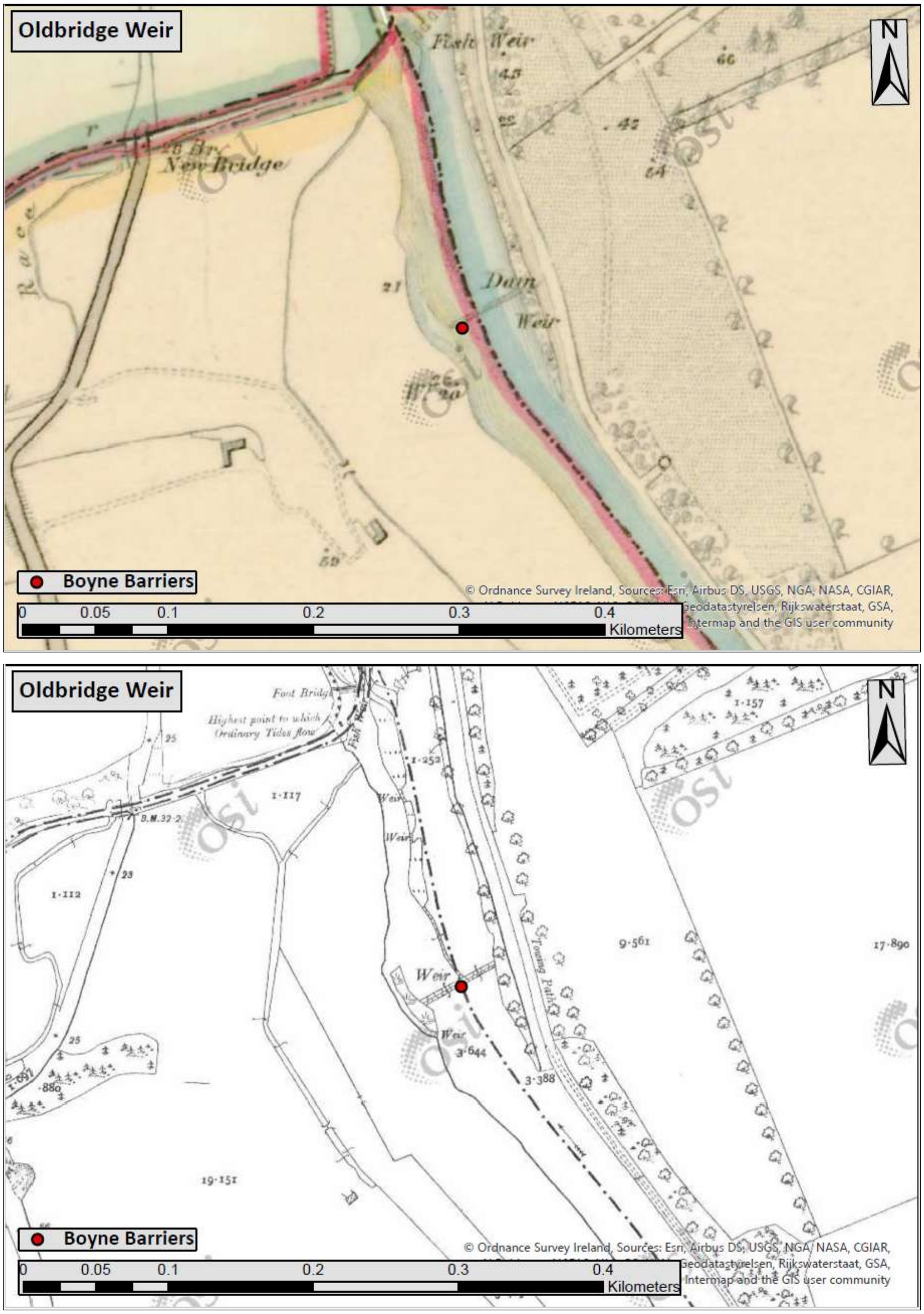


Figure 4. Location of Oldbridge Weir as shown on the historic 6" First Edition OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom). A tow path can be seen running beside the canal on the right-hand side of the river on the 25" map.

On the date of survey, the water height at Slane Castle gauging station (07012) was 0.596 m. The weir presented three transversal sections, all of which had sloping facets, for fish to attempt passage (Figure 5). The hydraulic head height varied from 0.545 to 0.835 m. The total width of the barrier along the crest was 63 metres, of which 62 metres were wetted. The total width of the channel at this point was 65 metres.

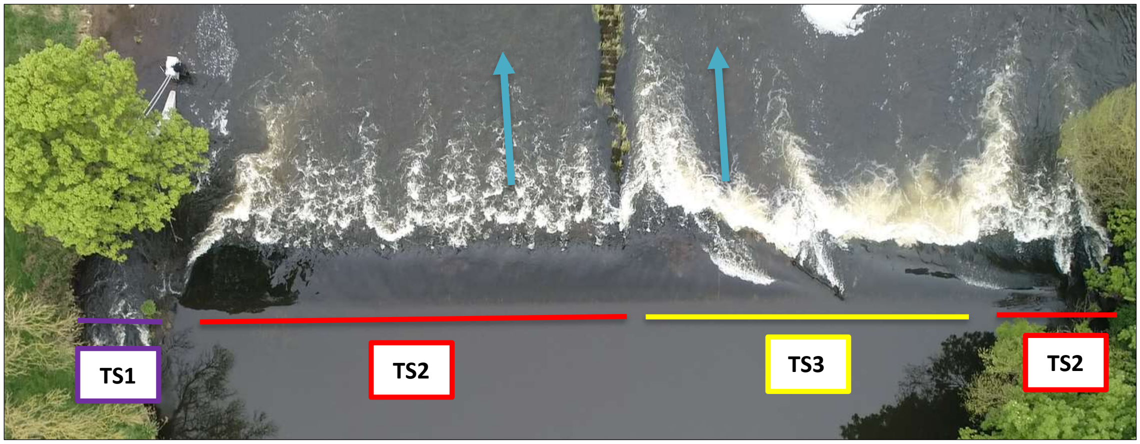


Figure 5. The three transversal sections of Oldbridge Weir. Drone imagery taken 24/04/2019.

Transversal 1:

Figure 6. Transversal Section 1.

In prevailing conditions, the effective length (10.8 m) of this sloping section of weir created a high impact partial barrier (score 0.3) for the upstream migration of cyprinids, adult lamprey, and juvenile salmonids (Figure 6). The same effective length presented a low impact partial barrier for adult salmonids. The available climbing substrate meant that juvenile eel encountered no barrier (score 1.0) at this passage option. Downstream migrants faced no barrier (score 1.0) at this transversal due to sufficient depths and low velocities at the crest. Higher flows would be unlikely to improve the passability of species other than salmonids.

Transversal 2:

Figure 7. Transversal Section 2.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream migration of juvenile eel. The streambed velocities at the outlet and midpoint created an insurmountable swim barrier for the species. Cyprinids, adult lamprey, and juvenile salmonids encountered a high impact partial barrier (score 0.3) when migrating upstream, primarily due to medium levels of turbulence (Figure 7). The turbulence also restricted passage for adult salmonids, although to a lesser extent. For adult salmon and adult trout, a low impact partial barrier (score 0.6) was established by the medium levels of turbulence. Migrants traversing the slope in a downstream direction encountered no barrier (score 1.0). In high flows, passability is unlikely to improve due to the potential for increased turbulence.

Transversal 3:

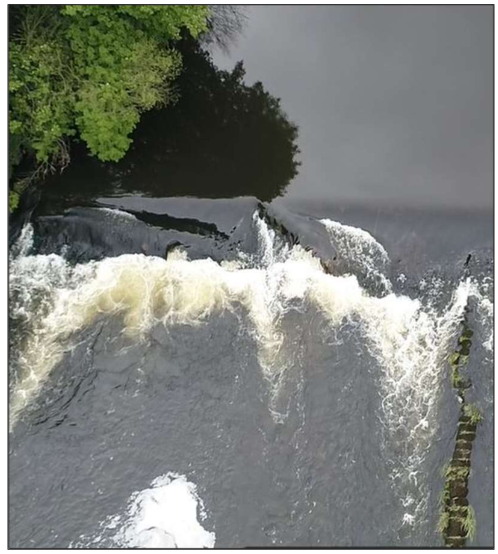


Figure 8. Transversal Section 3- facing upstream (left) and from above (right).

In prevailing conditions, this transversal was a high impact partial barrier (score: 0.3) for the upstream migration of cyprinids, adult lamprey, juvenile eel, and juvenile salmonids (Figure 8). Medium levels of turbulence and the slope (15.18%) were the primary obstacles. These factors also impeded the upstream migration of adult salmonids, creating a low impact partial barrier (score 0.6). Downstream migrants encountered no barrier (score 1.0). Higher flows are unlikely to improve the passability of this section of weir for any species.

Passability Assessment for Site (Table 1)

On the date of survey, salmonids, cyprinids, and adult lamprey migrating upstream encountered the same passability at all three transversals. Adult trout and adult salmon experienced a low impact partial barrier (score 0.6), while cyprinids, adult lamprey, and juvenile salmonids were presented with a high impact partial barrier (score 0.3). Juvenile eel were completely obstructed at transversal 2 but could utilize transversals 1 and 3. A suitable climbing substrate at transversal 1 rendered the structure no barrier (score 1.0) to their passage. Transversal 1 facilitated the best passage overall for upstream migration. Downstream migrants encountered no barrier (score 1.0) at all transversals and could avail of a number of routes to traverse the weir. Increased flows would be unlikely to improve the overall passability of this structure for species other than salmonids.

Table 1: Final Passability Assessment for Oldbridge Weir

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0	**No barrier** 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0
Adult Salmon	current conditions		✘			✘			
(AS)	high flows	✘				✘			
Adult Trout	current conditions		✘			✘			
(AT)	high flows	✘				✘			
Cyprinids	current conditions			✘		✘			
(C)	high flows			✘		✘			
Adult Lamprey	current conditions			✘					
(AL)	high flows			✘					
Juvenile Eel	current conditions	✘							
(JE)	high flows	✘							
Juvenile	current conditions			✘		✘			
Salmonids (JS)	high flows		✘			✘			
Juvenile	current conditions					✘			
Lamprey (JL)	high flows					✘			
Adult Eel	current conditions					✘			
(AE)	high flows					✘			

2. Dowth Weir

River: Boyne	Survey Date: 31/08/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, J O'Connor
River Basin District: ERBD	Grid ref: 702455, 772896
River Water Body: 07_1657_74	Name of Structure: Dowth Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

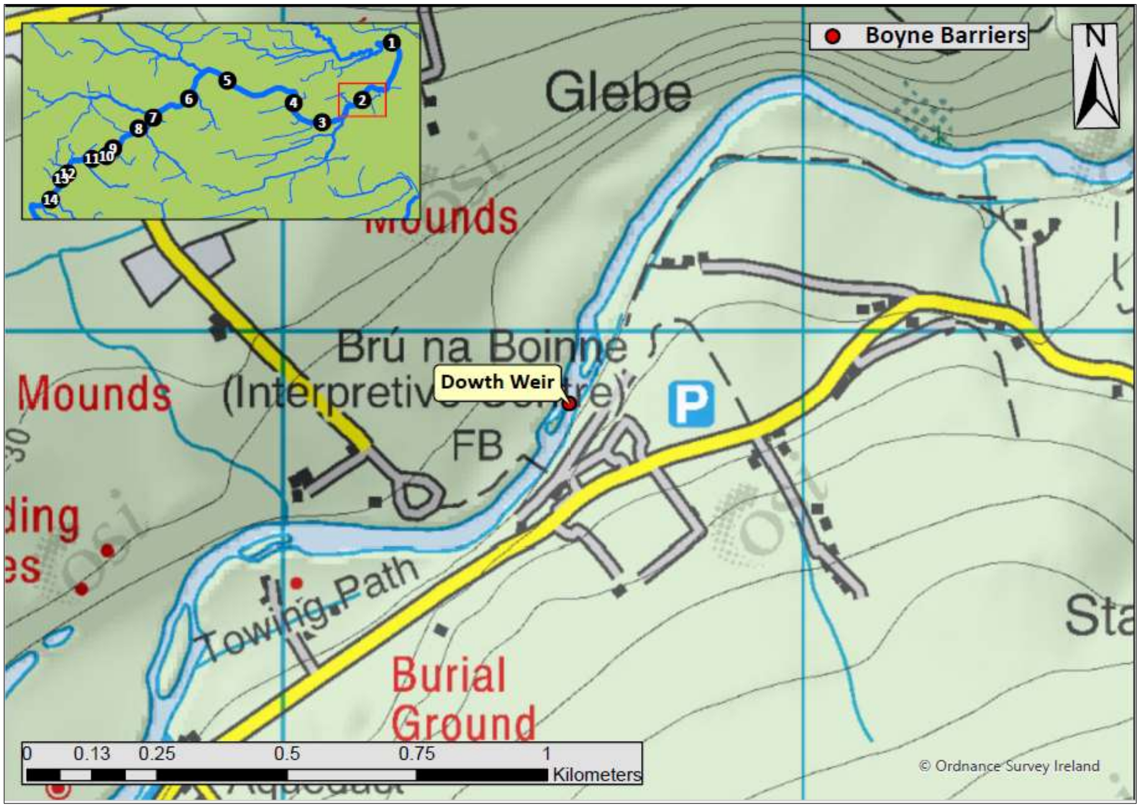
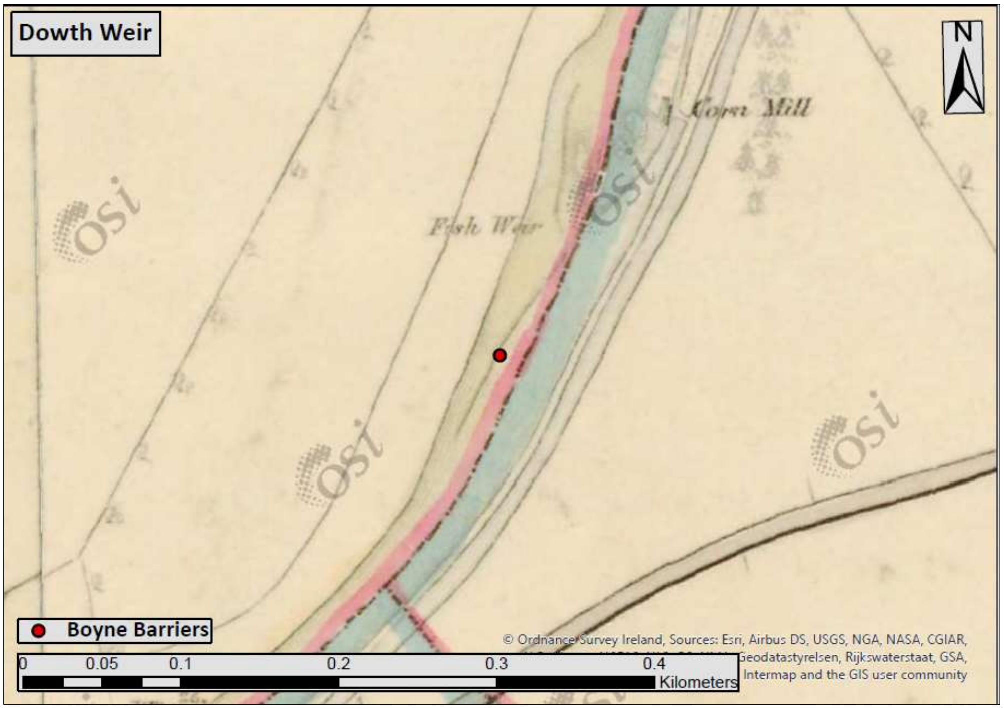


Figure 9. The location of Dowth Weir, Co. Meath.

Dowth Weir is located on the main stem of the River Boyne, Co. Meath (Figure 9). It is located 3.96 km upstream of Oldbridge Weir and rests on the border between the townlands of Dowth and Stalleen. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Good" ecological status. A fish weir is visible on the historic 6" First Edition OSi maps (1829-1841), suggesting that a structure has existed in this location since at least the early 19th century (Figure 10). The corn mill downstream of the weir, visible only on the 6" map, has potentially been the site of a mill since pre-1700 (NMS, 2020). The current Dowth Weir is in close proximity to the original site of a 14th century weir owned by the medieval Cistercian abbey of Mellifont (Went, 1953). Beside the weir is a site noted for recurring flood events (ID-935) (OPW, 2019). It is also an area with a high probability of flooding and an AEP of 10%.



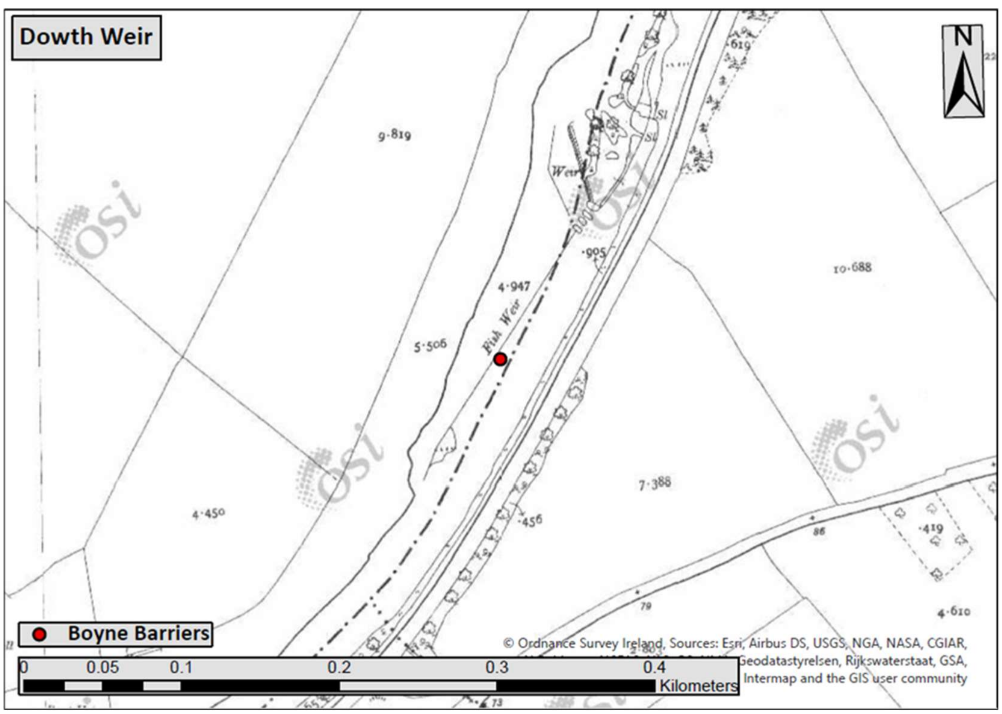


Figure 10. Location of Dowth Weir as shown on the historic 6" First Edition OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the water height at Slane Castle gauging station (07012) was 0.596 m. The hydraulic head height of the weir measured 0.44 m. The total width of the barrier along the crest was 402.4 m metres, while the total width of the channel at this point was 55.8 metres. The weir presented two transversal sections for fish to attempt passage (Figure 11), which are described below.

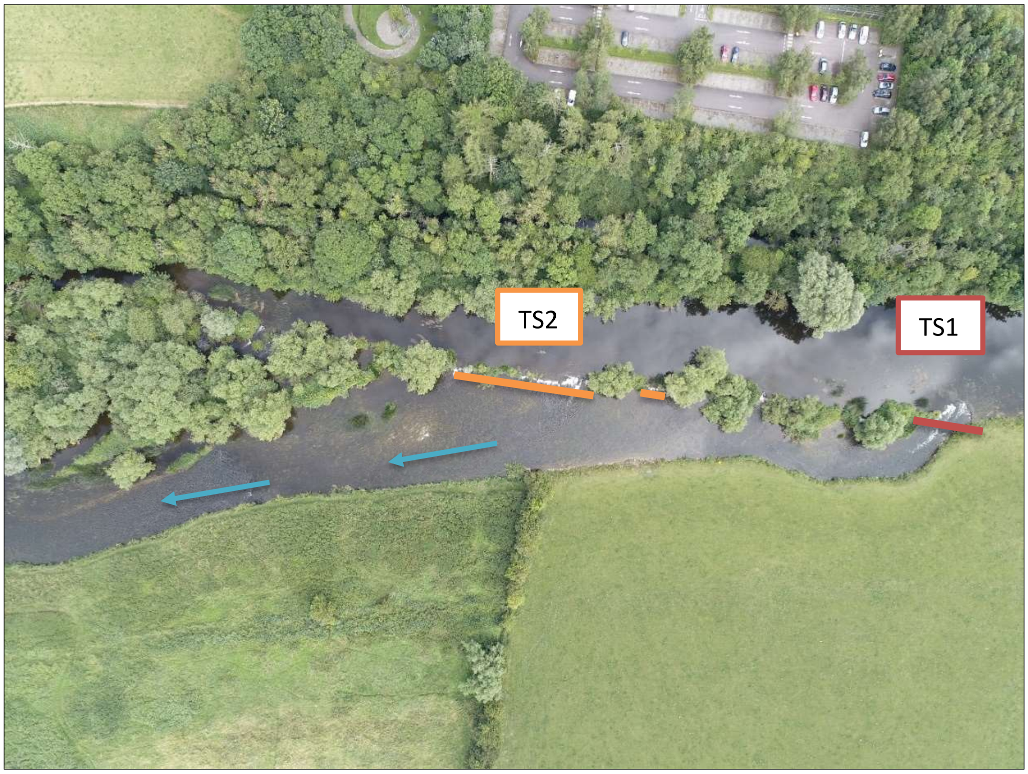


Figure 11. The two transversal sections of Dowth Weir. Drone imagery taken 15/07/2021.

Transversal 1:

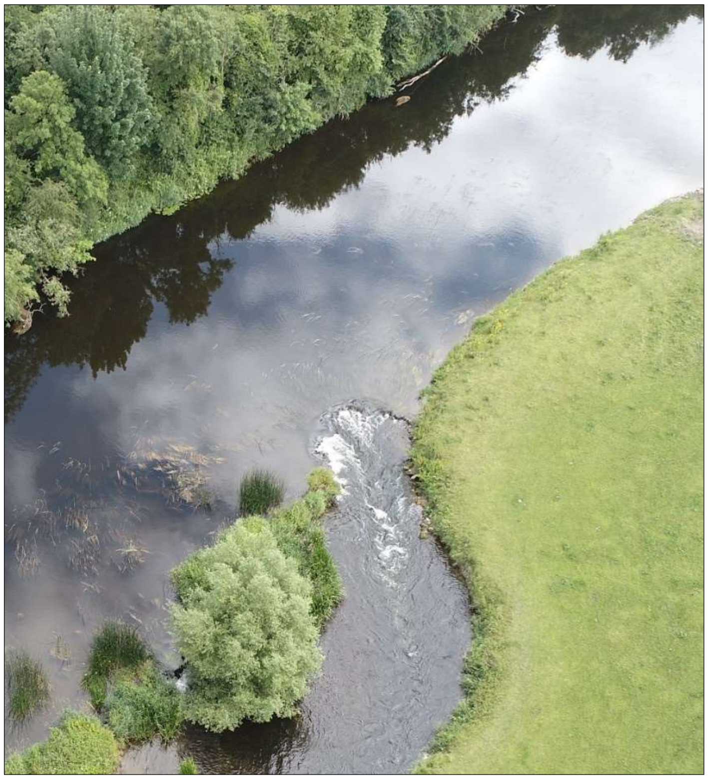


Figure 12. Transversal Section 1.

In prevailing conditions, the effective length (8.5 m) of this transversal was a barrier to all upstream migrating species except adult salmonids and juvenile eel (Figure 12). Juvenile eel could bypass what would have been a high impact partial barrier (score 0.3) by utilizing the available climbing substrate. Cyprinids traversing this section of the weir, however, had no alternative to the high impact partial barrier (score 0.3) created by the effective length. Juvenile salmonids and adult lamprey were impacted to a lesser degree, with the effective length representing a low impact partial barrier (score 0.6). Downstream migrants encountered no barrier (score 1.0) to passage at this transversal. Higher flows are unlikely to improve the passability of this section of weir for any species.

Transversal 2:

Figure 13. Transversal Section 2.

In prevailing conditions, the standing wave present at this transversal created a high impact partial barrier (score 0.3) for all species migrating upstream (Figure13). Medium levels of turbulence and high velocities at the outlet and midpoint compounded the challenge of upstream passage. Juvenile eel were able to circumvent the obstacles to passage by utilizing the available climbing substrate. However, cyprinids encountered a complete barrier (score 0.0) at this transversal due to the velocities. Downstream migrants faced no barrier (score 1.0) at this transversal. Higher flows are unlikely to improve passage for any species at this transversal.

Passability Assessment for Site (Table 2)

On the date of survey, all species other than cyprinids could utilise both transversal 1 or 2 for upstream migration. A suitable climbing substrate at both options meant no barrier (score 1.0) was encountered by juvenile eel. Transversal 1 offered better passage overall than transversal 2. Cyprinids had only one passage option available, transversal 1, as transversal 2 was a complete barrier (score 0.0) for this species. Downstream migration was unhindered at both transversals, offering similar passability. Higher flows would be unlikely to improve the passability for any species at either transversal.

Table 2: Final Passability Assessment for Dowth Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions	✘				✘			
	high flows	✘				✘			
Adult Trout (AT)	current conditions	✘				✘			
	high flows	✘				✘			
Cyprinids (C)	current conditions			✘		✘			
	high flows			✘		✘			
Adult Lamprey (AL)	current conditions		✘						
	high flows		✘						
Juvenile Eel (JE)	current conditions	✘							
	high flows	✘							
Juvenile Salmonids (JS)	current conditions		✘			✘			
	high flows		✘			✘			
Juvenile Lamprey (JL)	current conditions					✘			
	high flows					✘			
Adult Eel (AE)	current conditions					✘			
	high flows					✘			

3. Roughgrange Weir

River: Boyne	Survey Date: 15/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 700613, 771821
River Water Body: 07_1702_56	Name of Structure: Roughgrange Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

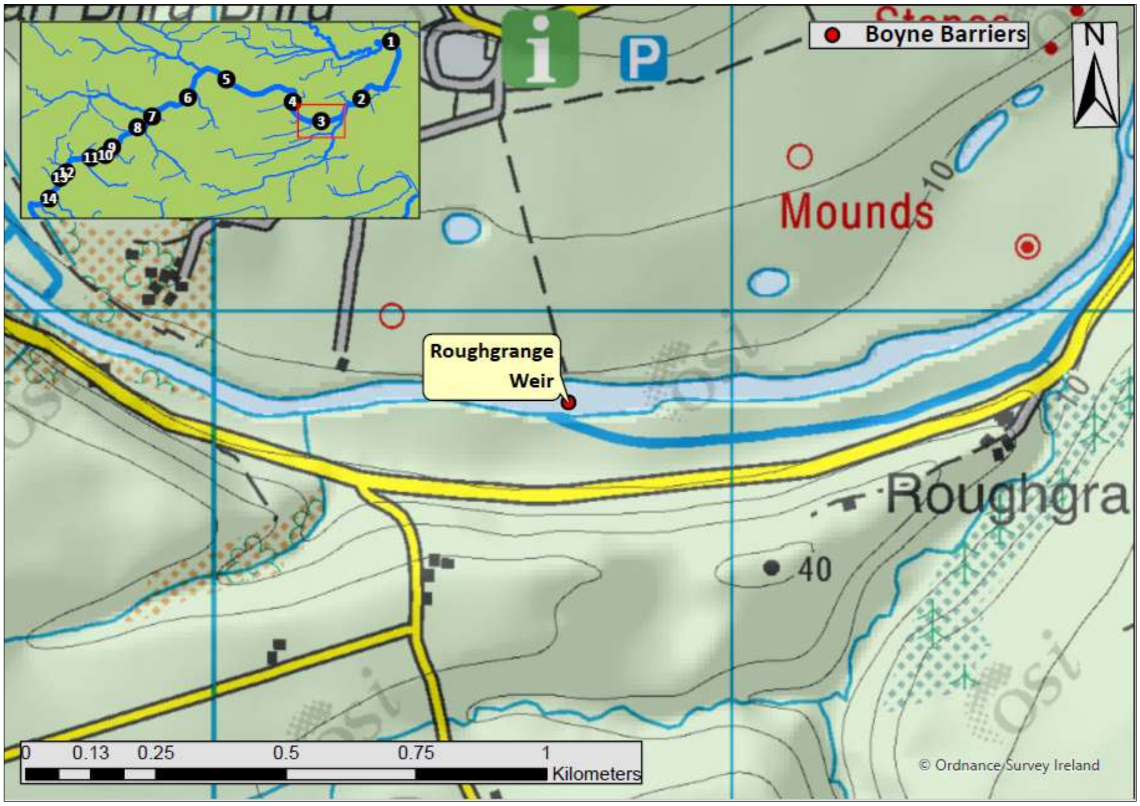


Figure 14. The location of Roughgrange Weir, Co. Meath.

Roughgrange Weir is located on the main stem of the River Boyne, Co. Meath (Figure 14). It is located 2.41 km upstream of Dowth Weir and is 6.36 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Roughgrange and Newgrange. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Good" ecological status. A dam is visible on the historic 6" First Edition OSi maps (1829-1841), suggesting that a structure has existed in this location since at least the early 19th century (Figure 15). Upstream of the weir is a site noted for recurring flood events (ID-936) (OPW, 2019). It is also an area with a high probability of flooding and an AEP of 10%.

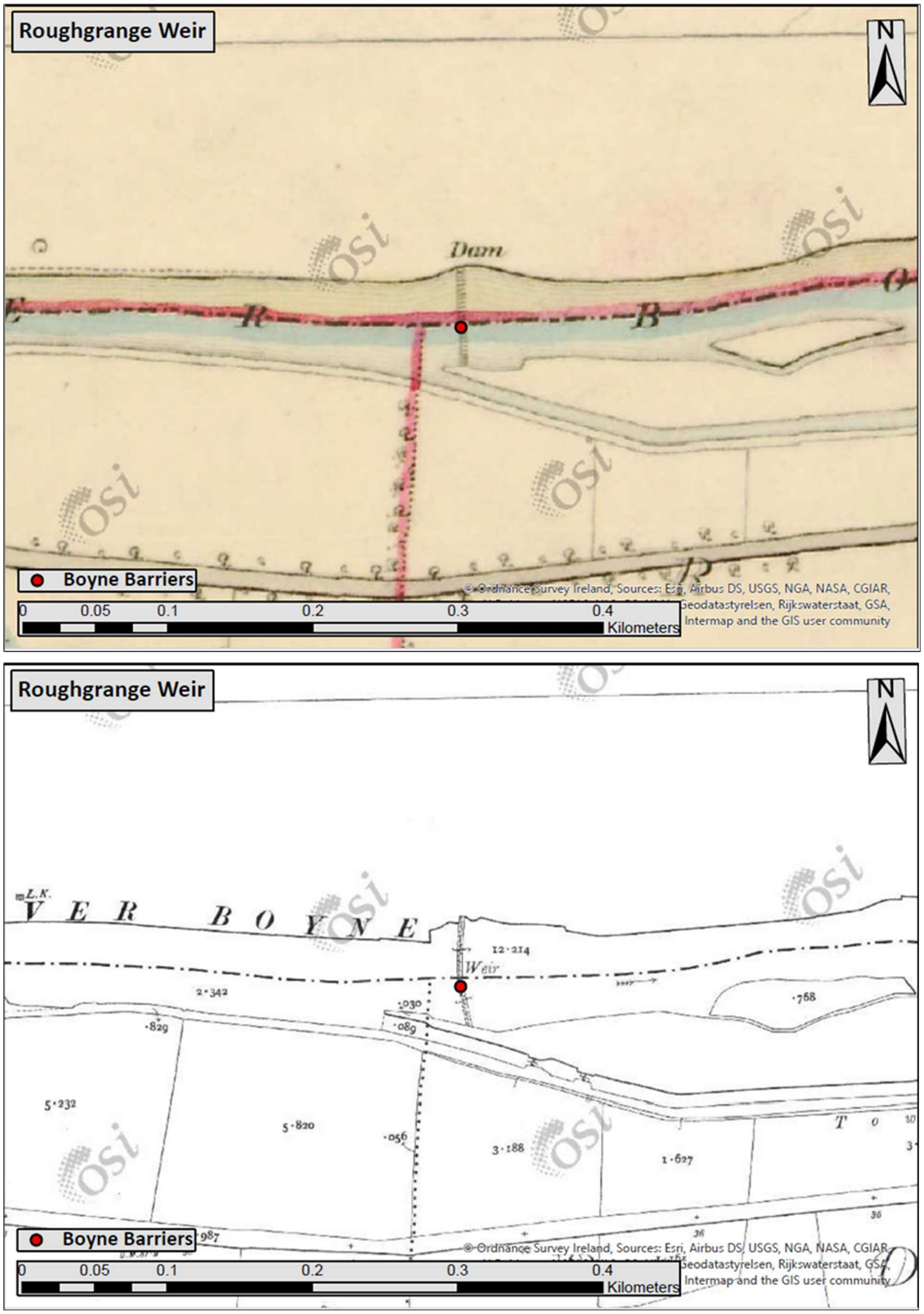


Figure 15. Location of Roughgrange Weir as shown on the historic 6" First Edition OSi map, 1829-1841, (top) and on the Historic 25" OSi map, 1897-1913, (bottom). The structure was originally labelled as a "Dam" but is referred to as a "Weir" in later map editions.

On the date of survey, the water height at Slane Castle gauging station (07012) was 0.616 m. The hydraulic head height of the weir measured 0.43 metres. The total width of the barrier along the crest was 78 metres. The structure crossed the river at a nearly 90-degree angle, as demonstrated by the similar channel (77.09 m) and barrier crest (78 m) widths (Figure 16). The sloping weir presented a single transversal section for fish to attempt passage (Figure 16), which is described below.

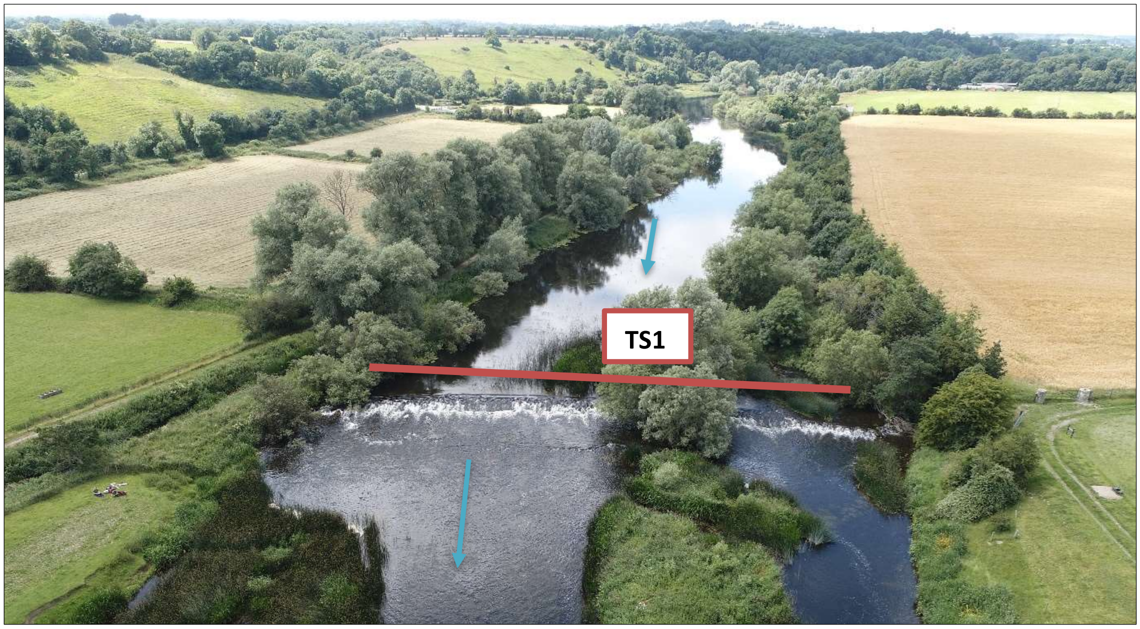


Figure 16. The single transversal section of Roughgrange Weir. Drone imagery taken 15/07/2021.

Transversal 1:

Figure 17. Transversal Section 1.

In prevailing conditions, this structure was a high impact partial barrier (score 0.3) to the upstream migration of all species except adult salmonids (Figure 17). Medium levels of turbulence were the primary issue. Adult salmonids were impacted to a lesser extent by turbulence and were met with a low impact partial barrier (score 0.6). Downstream migrants faced no barrier to passage (score 1.0) at this weir due to a lack of debris or damaging structures blocking the structure. Additionally, the crest supplied adequate depths and traversable velocities. Higher flows would be unlikely to improve the passage scores for any species.

Passability Assessment for Site (Table 3)

On the date of survey, only a single transversal, without alternatives, was available for fish to navigate the Roughgrange Weir. Medium levels of turbulence were the primary factor reducing the passability of the structure. Adult salmonids were best equipped to overcome the swim barrier and faced a low impact barrier (score 0.6). However, for juvenile salmonids, adult lamprey, juvenile eel, and cyprinids the issues represented a high impact partial barrier (score 0.3). Species traversing the barrier in a downstream direction were unhindered (score 1.0). Increased water flow would be unlikely to improve passage as the advantage of a reduced hydraulic head height could be negated by escalated water velocities and turbulence levels.

Table 3: Final Passability Assessment for Roughgrange Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0	**No barrier** 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0
Adult Salmon	current conditions		✘			✘			
(AS)	high flows		✘			✘			
Adult Trout	current conditions		✘			✘			
(AT)	high flows		✘			✘			
Cyprinids	current conditions			✘		✘			
(C)	high flows			✘		✘			
Adult Lamprey	current conditions			✘					
(AL)	high flows			✘					
Juvenile Eel	current conditions			✘					
(JE)	high flows			✘					
Juvenile	current conditions			✘		✘			
Salmonids (JS)	high flows			✘		✘			
Juvenile	current conditions					✘			
Lamprey (JL)	high flows					✘			
Adult Eel	current conditions					✘			
(AE)	high flows					✘			

4. Newgrange Weir

River: Boyne	Survey Date: 15/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 699277, 772745
River Water Body: 07_1447_19	Name of Structure: Newgrange Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

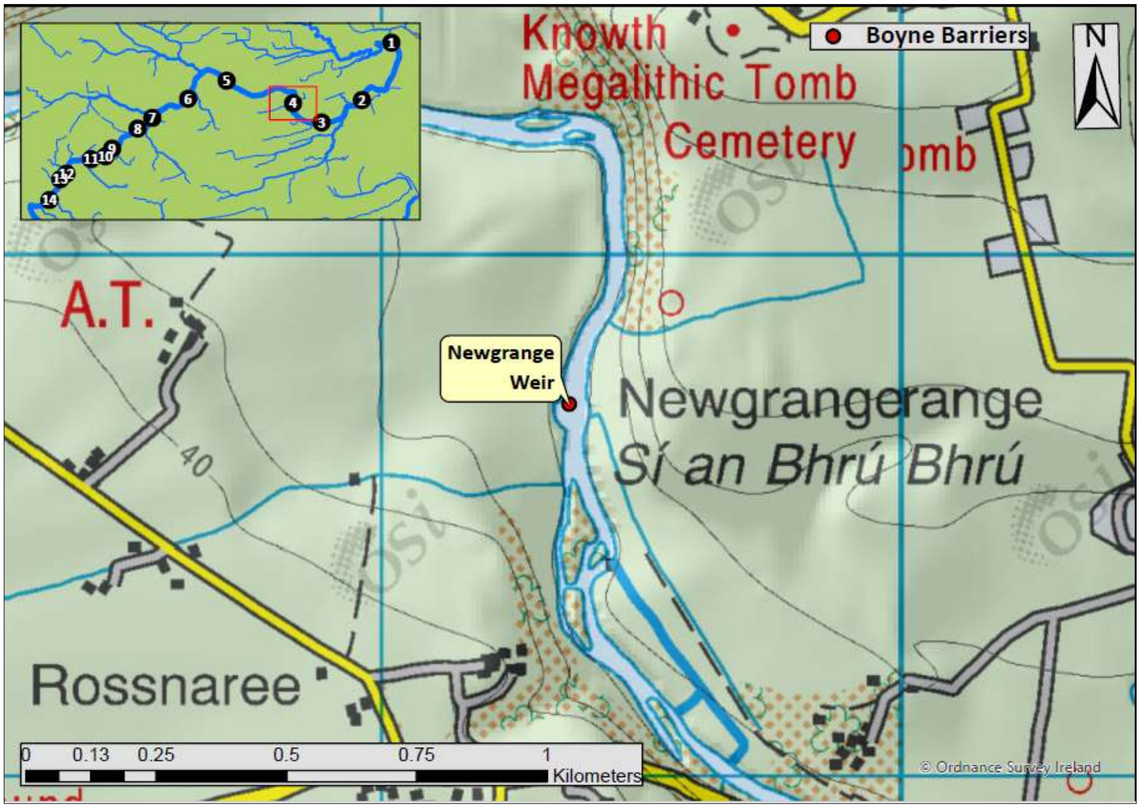


Figure 18. The location of Newgrange Weir, Co. Meath.

Newgrange Weir is located on the main stem of the River Boyne, Co. Meath (Figure 18). It is located 1.91 km upstream of Roughgrange Weir and is 8.27 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Rossnaree and Newgrange. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Good" ecological status. A weir is visible on the historic 6" First Edition OSi maps (1829-1841), suggesting that a structure has existed in this location since at least the early 19th century (Figure 19). The canal seen in the historic maps on the left-hand bank is no longer in use. Immediately downstream of Newgrange Weir an additional fish weir can also be seen. The remnants of this structure remain in place. The fish weir was potentially built on or close to the original medieval fish weir of Rosnaree owned by the Cistercian abbey of Mellifont (Went, 1953). An area on the right-hand bank immediately upstream of the weir is labelled "Liable to flood" in the historic 25" map. This extent of land maintains a high probability of flooding with an AEP of 10%.

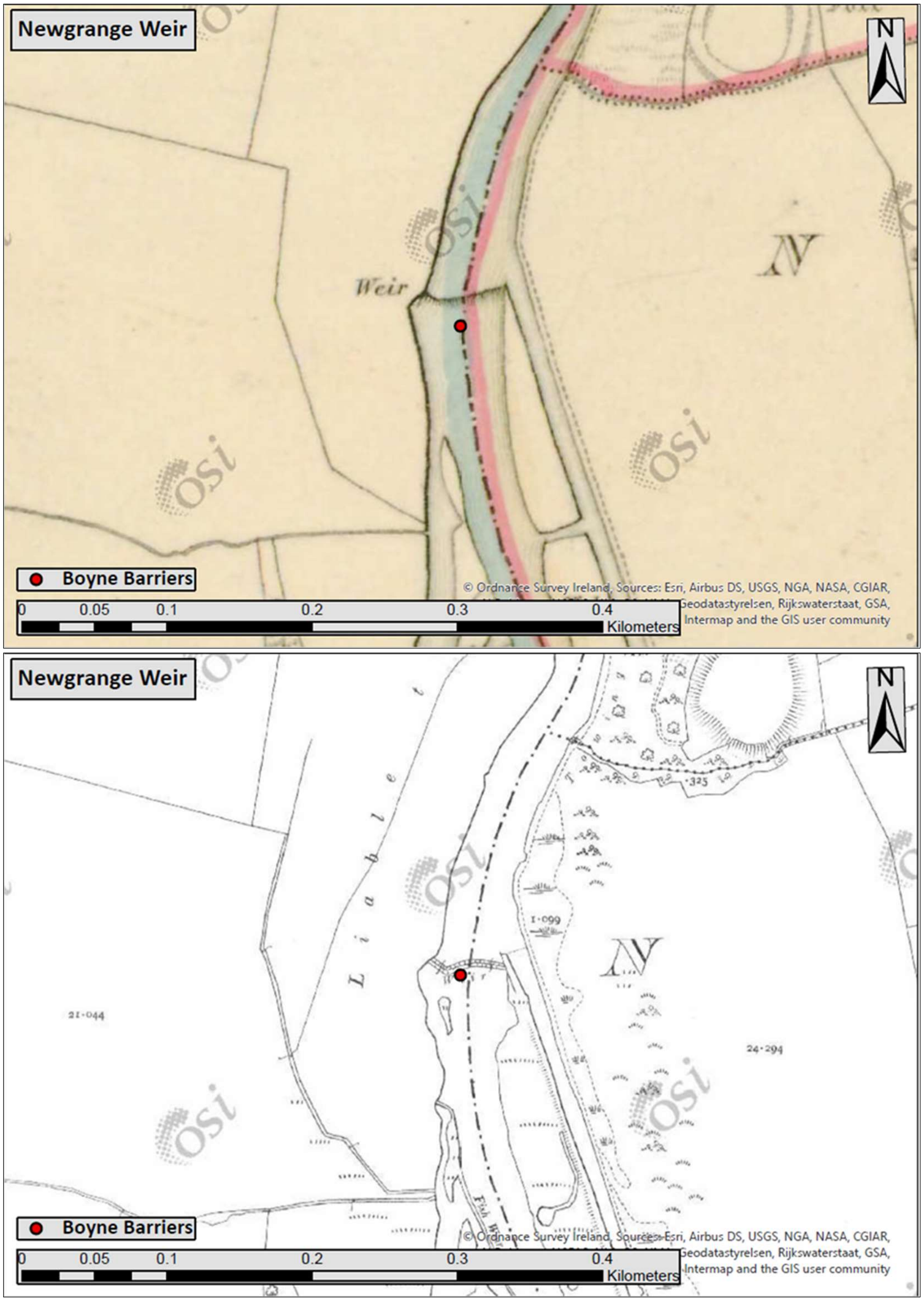


Figure 19. Location of Newgrange Weir as shown on the historic 6" First Edition OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the water height at Slane Castle gauging station (07012) was 0.616 m. The hydraulic head height of the weir measured 0.81 m. The total width of the barrier along the crest was 58 metres, all of which were wetted (Figure 20). The width of the channel at this point was 47 metres.

The sloping weir comprised of concrete and masonry and presented two transversal sections for fish to attempt passage (Figure 20), which are described below.

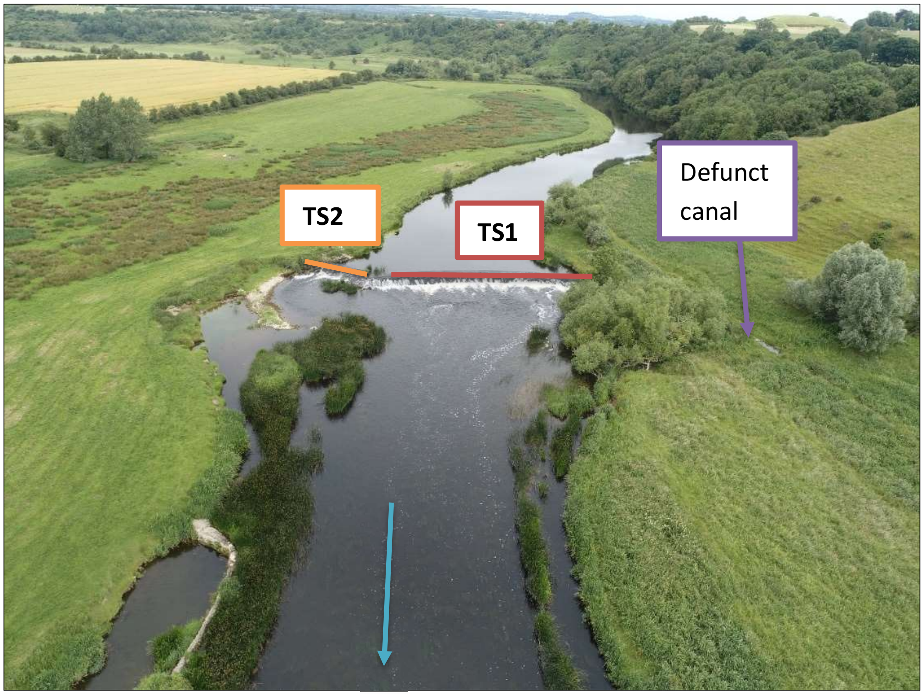


Figure 20. The two transversal sections of Newgrange Weir. Drone imagery taken 15/07/2021.

Transversal 1:

Figure 21. Transversal Section 1.

In prevailing conditions, this structure was a high impact partial barrier (score 0.3) to the upstream migration of all species except juvenile eel. The presence of a standing wave limited the progression of fish in an upstream direction (Figure 21). Due to the availability of a suitable climbing structure, juvenile eel were able to circumvent the aquatic elements and therefore encountered no barrier (score 1.0). The passage of cyprinids, adult lamprey, and juvenile salmonids was further obstructed by the slope (19.29%) and medium levels of turbulence. These factors created additional high impact partial barriers (score 0.3) for the species. Downstream migrants faced no barrier to passage (score 1.0) due to a lack of debris or damaging structures blocking the structure. Additionally, the crest supplied adequate depths and traversable velocities. Higher flows would be unlikely to improve the passage scores for any species.

Transversal 2:

Figure 22. Transversal Section 2.

In prevailing conditions, this structure was a high impact partial barrier (score 0.3) to the upstream migration of salmonids and adult lamprey. The presence of a standing wave severely limited their migratory progress (Figure 22). Cyprinids and juvenile eel were also hindered by the standing wave but faced a greater obstacle in the form of high velocities. At the outlet and midpoint, the water velocity created a complete swim barrier for these species (score 0.0). Compounding factors impeding upstream migration for all species were the slope (18.84%) and medium levels of turbulence. Downstream migrants faced no barrier to passage (score 1.0) at this transversal. Higher flows would be unlikely to improve the passage scores for any species.

Passability Assessment for Site (Table 4)

On the day of survey, Newgrange Weir was a high impact partial barrier (score 0.3) to all species migrating upstream, except juvenile eel. By availing of the climbing substrate at transversal 1, juvenile eel were able to circumvent the structure and encountered no barrier (score 1.0). Salmonids and adult lamprey could utilise transversal 1 or 2 to surmount the structure. These species were subject to a high impact partial barrier (score 0.3) at both, due to issues with slope, turbulence, and standing waves. However, high velocities at transversal 2 presented an additional challenge. Cyprinids and juvenile eel could only make passage at transversal 1, due to the prohibitive velocities at transversal 2. Therefore, transversal 1 offered the best passage overall. Downstream migrants were similarly facilitated at both passage options. Higher flows would be unlikely to improve passage for any species. The potential for increased turbulence and velocities would negate the benefits of a lowered hydraulic head height.

Table 4: Final Passability Assessment for Newgrange Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions			X		X			
	high flows			X		X			
Adult Trout (AT)	current conditions			X		X			
	high flows			X		X			
Cyprinids (C)	current conditions			X		X			
	high flows			X		X			
Adult Lamprey (AL)	current conditions			X					
	high flows			X					
Juvenile Eel (JE)	current conditions	X							
	high flows	X							
Juvenile Salmonids (JS)	current conditions			X		X			
	high flows			X		X			
Juvenile Lamprey (JL)	current conditions					X			
	high flows					X			
Adult Eel (AE)	current conditions					X			
	high flows					X			

5. Slane Weir

River: Boyne	Survey Date: 14/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 696219, 773776
River Water Body: 07_1057_11	Name of Structure: Slane Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

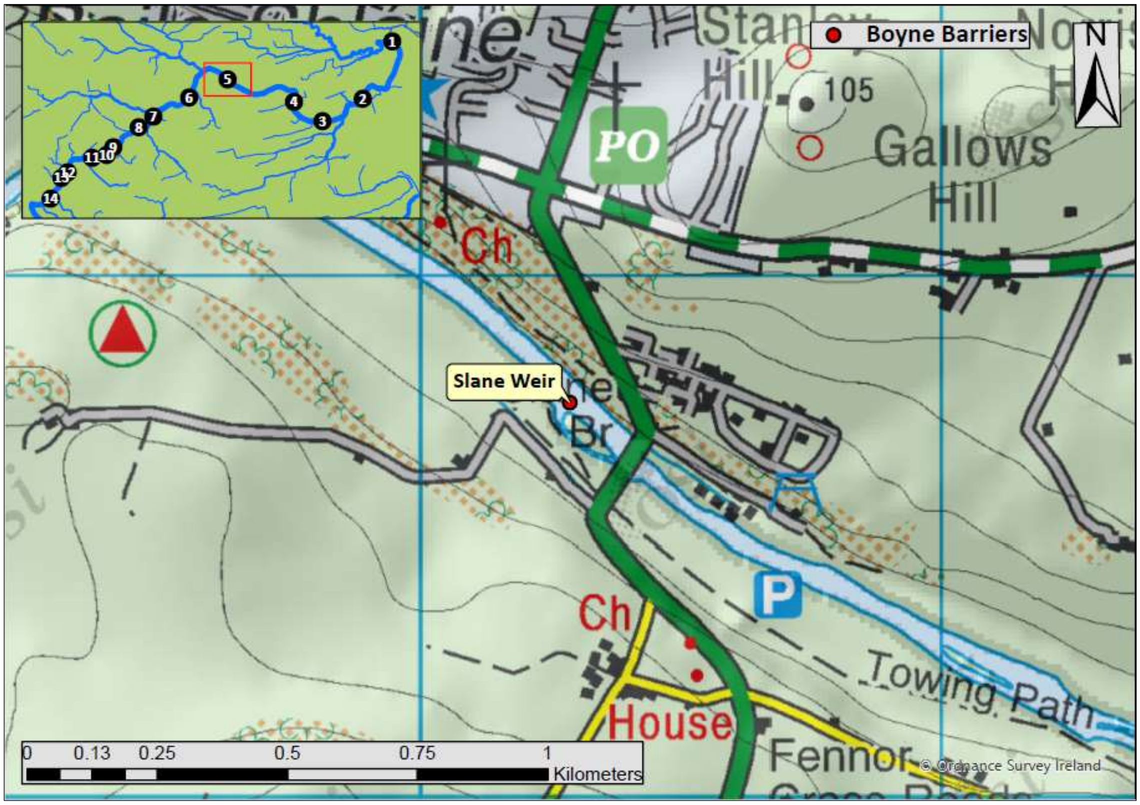


Figure 23. The location of Slane Weir, Co. Meath.

Slane Weir is located on the main stem of the River Boyne, Co. Meath (Figure 23). It is located 3.98 km upstream of Newgrange Weir and is 12.24 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Slanecastle Demesne and Fennor. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. This stone weir dates from 1765 and was erected to divert water to the mill race of the Slane Flour Mill (NMS, 2020). During the early 20th century, the water wheels were removed, and the mill adapted for the manufacture of textiles. The historic 25" OSi maps record an area between the canal and the right-hand bank of the river as liable to flood (Figure 25). This extent of land retains a high probability of flooding with an AEP of 10% (Figure 24). Recurring flood events are also recorded upstream of the weir (Flood ID-937), with the area prone to flooding one or two times a year.

Figure 24. Flood event (ID-1958) at Slane Bridge, February 1990 (looking downstream). Photo from Floodinfo.ie (OPW, 2019).

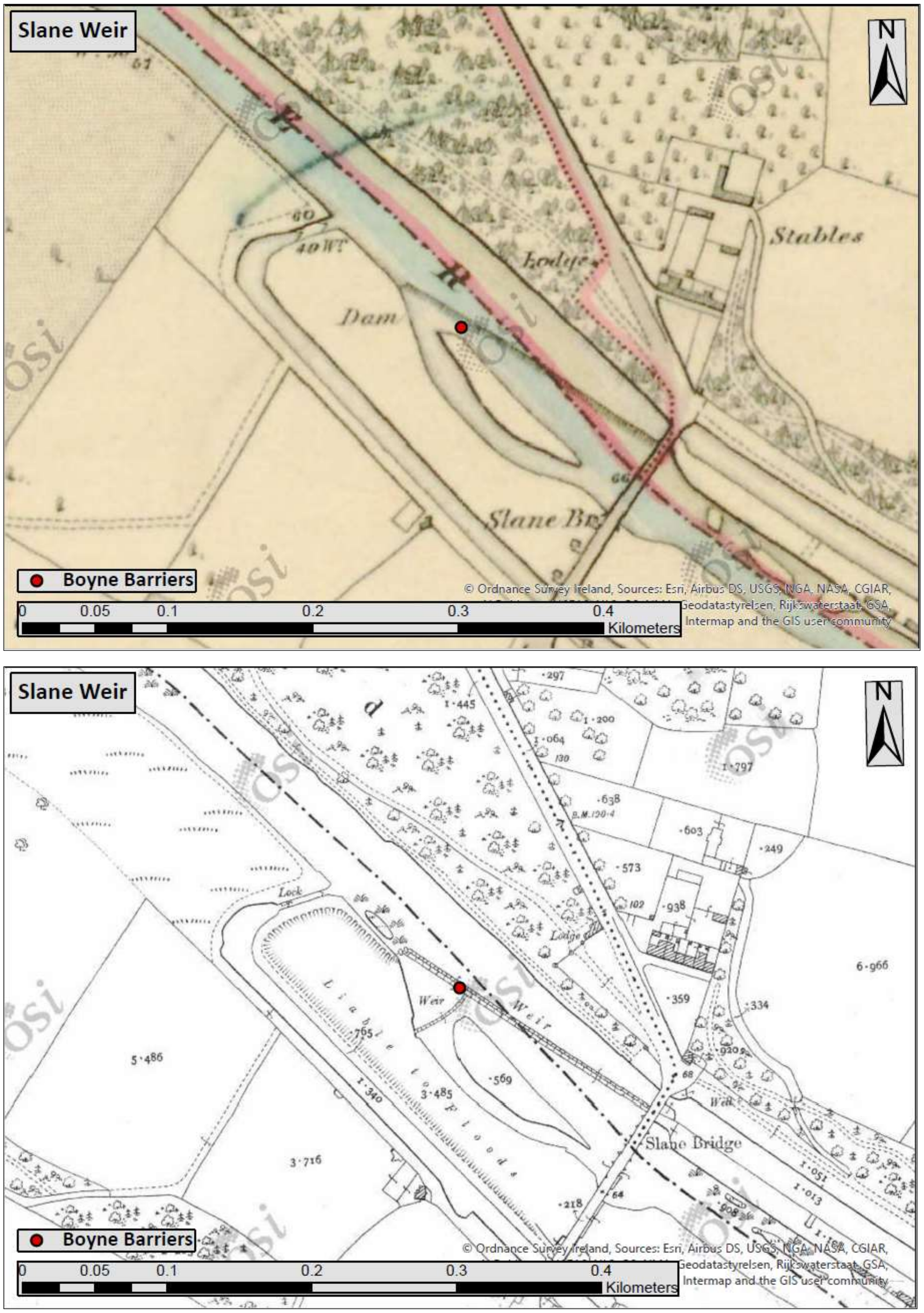


Figure 25. Location of Slane Weir as shown on the historic 6" First Edition OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Slane Castle gauging station (07012) was 0.624 m. The hydraulic head height of the weir varied from 0.74 to 0.75 m. The total width of the barrier along the crest was 208.79 metres, excluding the perpendicular section containing transversal 5. The width of the channel at this point was 82.68 metres. The sloping weir presented five transversal sections for fish to attempt passage (Figure 26), which are described below.

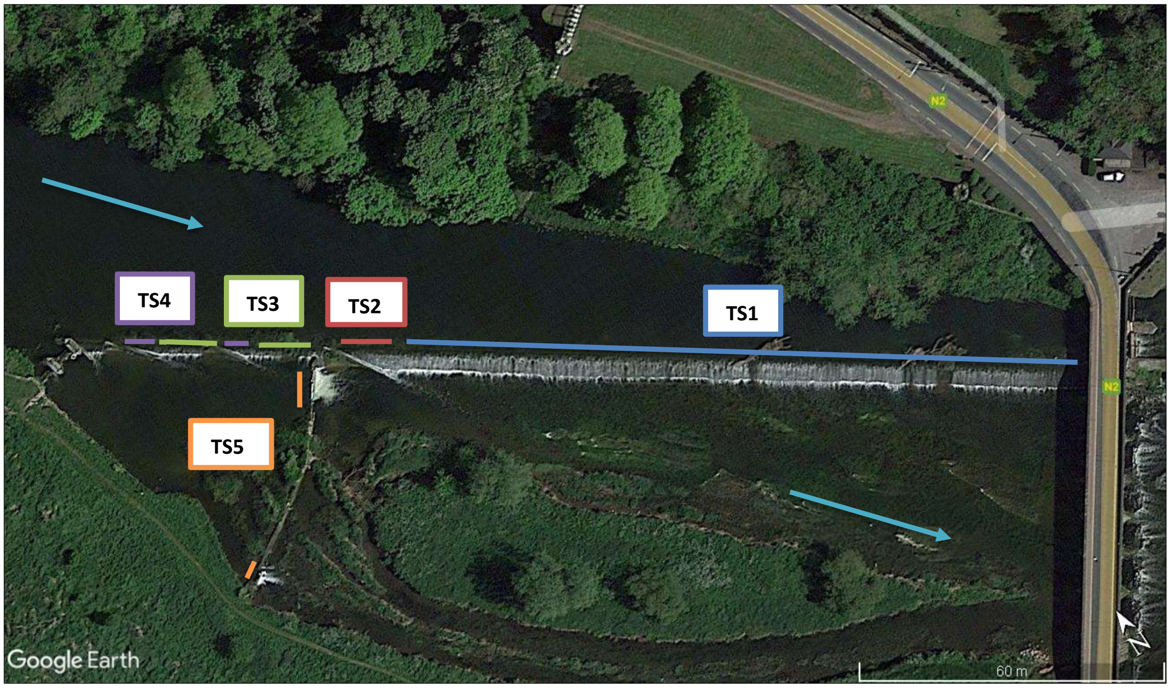


Figure 26. The five transversal sections of Slane Weir. Imagery from 05/07/2017, *Google Earth*, earth.google.com/web/.

Transversal 1:

Figure 27. Transversal Section 1.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream migration of all species, except for adult lamprey and juvenile salmonids (Figure 27). The consistently low depths across this passage option, but particularly at the outlet (0.04 to 0.05m) and midpoint (0.04 to 0.05 m) were the primary inhibiting factor. However, for juvenile eel it was not the depths, but the velocities greater than 0.8m/s that prevented upstream passage. Adult lamprey and juvenile salmonids were also impacted by the low depths, but to a lesser extent. These species encountered a high impact partial barrier (score 0.3). A compounding factor was the slope (17.21%) of the transversal, which separately constituted a high impact partial barrier (score 0.3) for adult lamprey, cyprinids, and juvenile salmonids.

The progress of downstream migrants was similarly disrupted by the depth of water flowing over the structure. However, the crest depths (0.05 to 0.07 m) were marginally better than those at the outlet and midpoint. Adult salmon faced a complete barrier (score 0.0), while adult trout and cyprinids were presented with a high impact partial barrier (score 0.3). Once again, adult lamprey and juvenile salmonids fared better in the low depths, meeting a low impact partial barrier (score 0.6). Juvenile lamprey migrating downstream were confronted with no barrier at all (score 1.0).

As depth is the predominant limiting factor, higher flows would be likely to improve passability for all species, except juvenile eel, both upstream and downstream. As water velocities were the primary concern for juvenile eel, increased volume would be likely to exacerbate rather than to alleviate this limiting factor.

Transversal 2:

Figure 28. Transversal Section 2.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream migration of cyprinids and juvenile eel. Salmonids and adult lamprey encountered a high impact partial barrier (score 0.3). The primary limiting factor to passage for all species were the velocities at the outlet (2.6 to 3.36 m/s). The lack of effective resting locations, medium levels of turbulence, and effective length

(12.4 m) were additional restrictive elements to upstream passage at this transversal (Figure 28). All downstream migrants, except adult salmon, traversed this section of weir without any issue. The downstream progress of adult salmon was hindered by low depths at the crest of the structure (0.06 to 0.1 m). Higher flows would be unlikely to improve the upstream passage of any species, as pressure from velocities would increase rather than decrease with rising water levels. However, with regard to downstream migrants, higher flows would raise depths and enhance the passage of adult salmon.

Transversal 3:

Figure 29. Transversal Section 3.

In prevailing conditions, this slope was a complete barrier (score 0.0) to the upstream migration of cyprinids and adult salmonids. Juvenile salmonids, juvenile eel, and adult lamprey were met with a high impact partial barrier (score 0.3). Low depths (0.04 to 0.06 m) across the transversal were the primary obstruction to passage affecting all species, except juvenile eel. Velocities at the outlet (0.57 to 1.33 m/s) were the main obstacle for juvenile eel. The slope (32.17%) was also a limiting factor. It created a low impact partial barrier (score 0.6) for adult salmonids, and a high impact partial barrier (score 0.3) for cyprinids, adult lamprey, and juvenile salmonids (Figure 29).

The passage of downstream migrating species was also impaired by low depths, in this case at the crest of the structure (0.05 to 0.06 m). Not all species were impacted to the same degree. Adult salmon encountered a complete barrier (score 0.0). Adult trout and cyprinids faced a high impact partial barrier (score 0.3). Juvenile salmonids and adult eel experienced a low impact partial barrier (score 0.6). Finally, juvenile lamprey were the only species to be unimpeded by the low depths and were met with no barrier (score 1.0) during their downstream migration.

Higher flows would be likely to improve the upstream and downstream passage of all species, except juvenile eel. With increased water flow, depths would rise and the primary obstacle to passage would be negated. However, increased flow would also likely increase velocities and potentially worsen the passage of juvenile eel.

Transversal 4:

Figure 30. Transversal Section 4.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream migration of adult salmon. For all other species, this section of weir represented a more surmountable high impact partial barrier (score 0.3). A combination of low depths at the crest (0.06 to 0.07 m) and high velocities at the outlet was the primary inhibitor to upstream passage (Figure 30). Medium levels of turbulence were an additional concern.

In addition to limiting upstream passage, low depths at the crest of the transversal also hindered downstream migrants. Adult salmon faced a complete barrier (score 0.0). Adult trout and cyprinids encountered a high impact partial barrier (score 03). Juvenile salmonids and adult eel experienced a low impact partial barrier (score 0.6). Finally, juvenile lamprey were the only species to be unobstructed by the low depths and were met with no barrier (score 1.0) during their downstream migration.

Higher flows would be likely to improve the upstream passage of adult salmonids. However, the remaining upstream migrants would not benefit from increased water flow due to their increased susceptibility to high velocities. The downstream passage of all species would be enhanced with higher flows. Depths would rise and the primary obstacle to passage would be negated.

Transversal 5:

Figure 31. Transversal Section 5.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream migration of all species, except adult salmonids and juvenile eel. The vertical hydraulic head height of 0.75 m was the primary obstacle (Figure 31). Juvenile eel were able to circumvent the transversal using the available climbing substrate. Therefore, this species encountered no barrier (score 1.0). For adult salmon the hydraulic head represented a low impact partial barrier (score 0.6). However, for adult trout, the vertical drop represented a high impact partial barrier (score 0.3).

All downstream migrants, with the exception of cyprinids, encountered no barrier (score 1.0) at this location. The presence of velocities between 1.16 and 1.5 m/s at the transversal crest hampered the species' progress by creating a low impact partial barrier (score 0.6).

Higher flows would be unlikely to alter the transversal's impact on downstream passage. However, the upstream passage of all species could be improved by increased water flow. The elevated water volumes would reduce the jump barrier created by the hydraulic head height and facilitate better passage. However, the required reduction to benefit adult salmonids is far less than would be required to impact the upstream passage of the remaining migrating species.

Passability Assessment for Site (Table 5)

On the day of survey, Slane Weir was a high impact partial barrier (score 0.3) to all species migrating upstream, except for juvenile eel and adult salmon. By availing of the climbing substrate at transversal 5, juvenile eel were able to circumvent the structure and encountered no barrier (score 1.0). Adult salmon were able to utilise the low impact partial barrier (score 0.6), also provided by transversal 5. Transversal 2 offered another viable passage route to adult salmon. However, this alternative route presented as a high impact partial barrier (score 0.3). The remaining species, regardless of passage route taken, were subjected to high impact partial barriers (score 0.3). However, some had a greater choice of routes than others. Juvenile salmonids could utilise transversals 1, 2, 3, and 4 to surmount Slane Weir. Cyprinids, on the other hand, were only facilitated by transversal 4. No single transversal was able to accommodate the passage of every upstream migratory species.

Downstream migrants were primarily best supported by transversal 5. All species, with the exception of cyprinids, faced no barrier (score 1.0) at this section of the weir. Cyprinids, however, were met with a low impact partial barrier (score 0.6). Transversal 2 provided more suitable downstream passage for the species. At this location, cyprinids encountered no barrier (score 1.0).

Higher flows have the potential to improve the upstream passage of salmonids and adult lamprey. Cyprinids would be unlikely to benefit due to the counter influence of increased turbulence at their available point of passage. With regard to downstream migration, higher flows would increase the choice and ease of passage routes available.

Table 5: Final Passability Assessment for Slane Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0	**No barrier** 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0
Adult Salmon (AS)	current conditions		X			X			
	high flows	X				X			
Adult Trout (AT)	current conditions			X		X			
	high flows		X			X			
Cyprinids (C)	current conditions			X		X			
	high flows			X		X			
Adult Lamprey (AL)	current conditions			X					
	high flows		X						
Juvenile Eel (JE)	current conditions	X							
	high flows	X							
Juvenile Salmonids (JS)	current conditions			X		X			
	high flows		X			X			
Juvenile Lamprey (JL)	current conditions					X			
	high flows					X			
Adult Eel (AE)	current conditions					X			
	high flows					X			

6. Carrickdexter Weir

River: Boyne	Survey Date: 8/09/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, G McManus
River Basin District: ERBD	Grid ref: 694437, 772940
River Water Body: 07_1086_170	Name of Structure: Carrickdexter Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

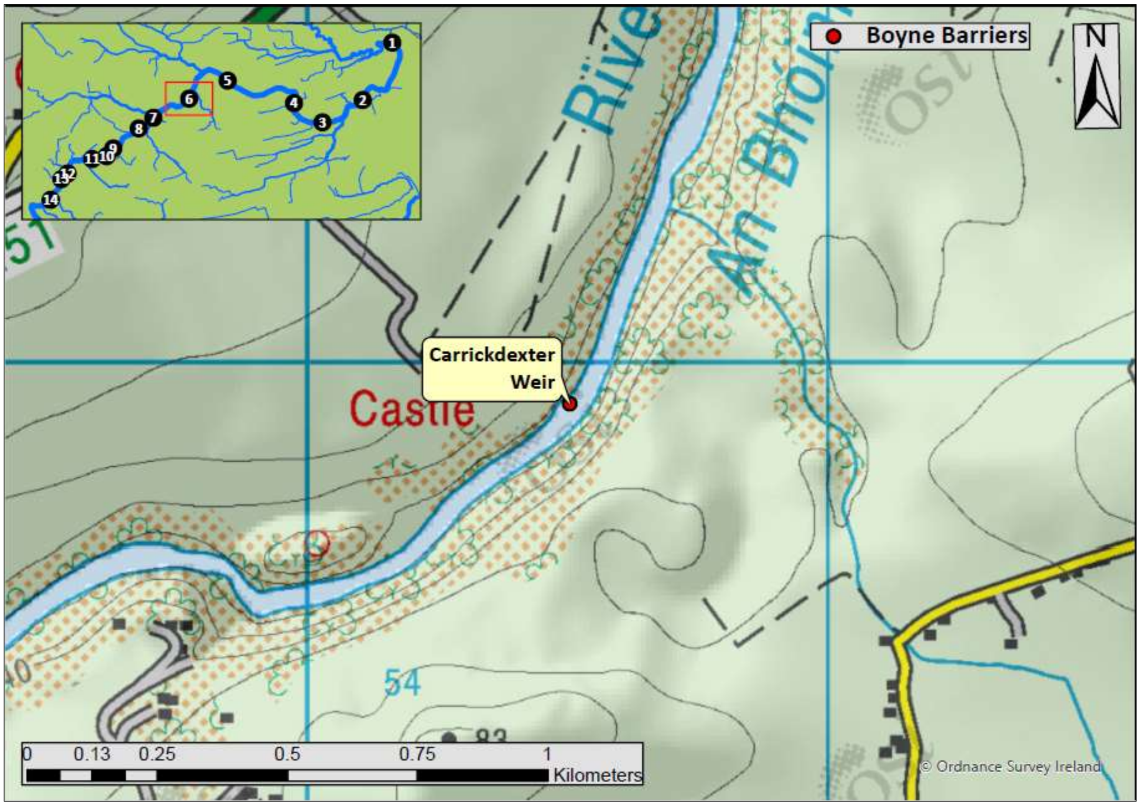
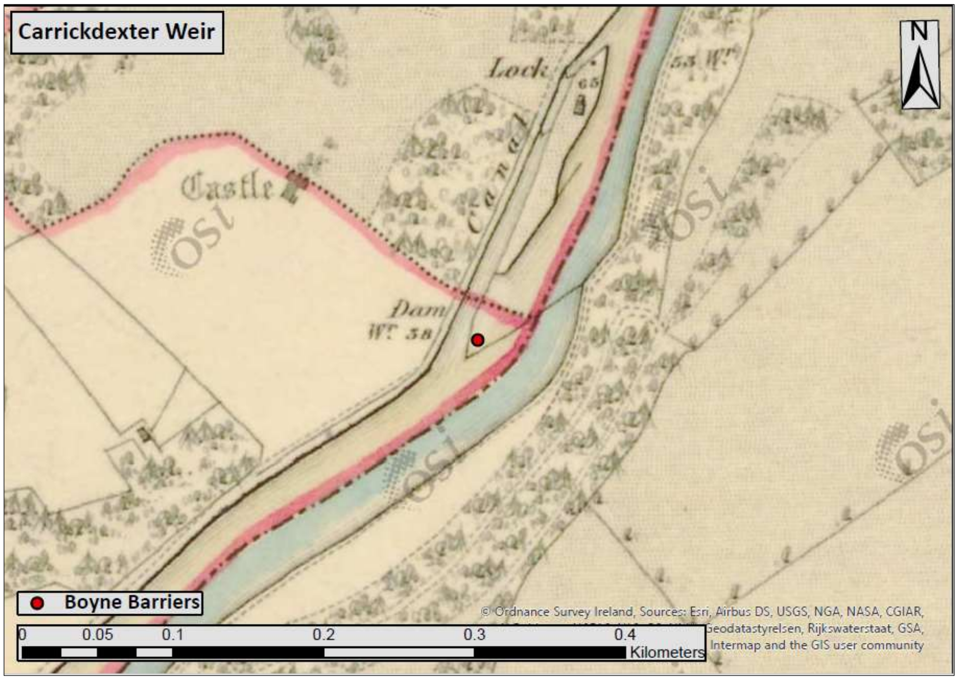


Figure 32. The location of Carrickdexter Weir, Co. Meath.

Carrickdexter Weir is located on the main stem of the River Boyne, Co. Meath (Figure 32). It is located 2.74 km upstream of Slane Weir and is approximately 15 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Slanecastle Demesne and Thurstianstown. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. The weir lies parallel to a castle and tower house dating from the 16th/ 17th century (NMS, 2020) (Figure 33). In 1640, the Lord of Slane was recorded as owning 185 acres in "Carrick Desert & Piggshills", containing a castle, a stone house, a weir, and two mills (Simington, 1940). Carrick Desert is an earlier anglicisation of the Irish term for the area, Carraig an Dísirt. The section of river immediately surrounding the weir suffered from surface water floods during the 2015/2016 winter season (OPW, 2019).



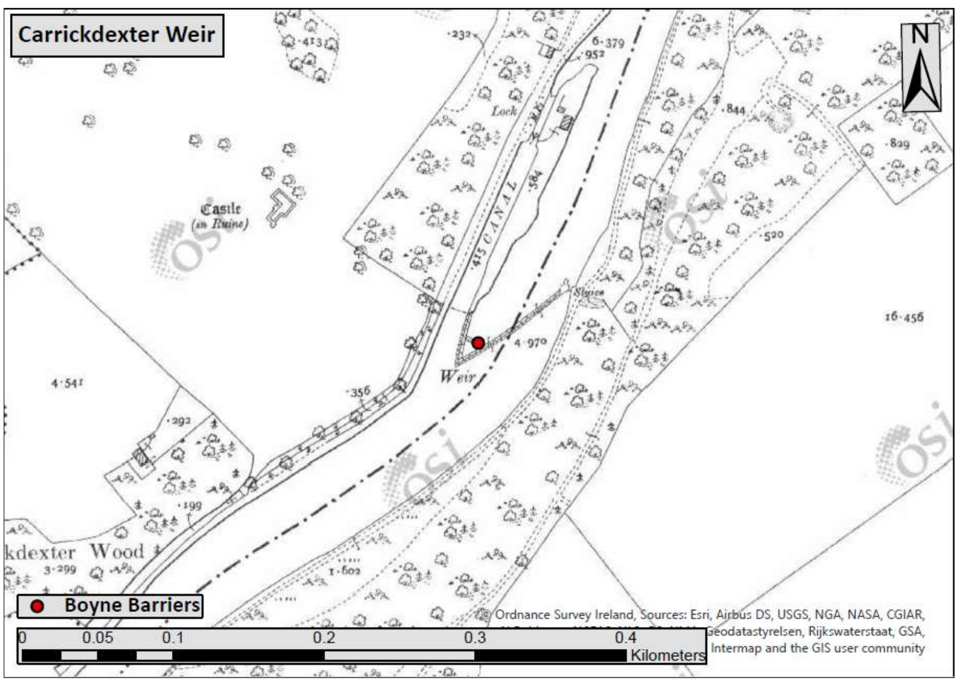


Figure 33. Location of Carrickdexter Weir as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Slane Castle gauging station (07012) was 0.573 m. The hydraulic head height of this horseshoe shaped weir was 1.593 m. The total width of the barrier along the crest was 122 metres, of which 104 metres were wetted. The width of the channel at this point was 50 metres. The sloping and stepped weir presented four transversal sections for fish to attempt passage (Figure 34), which are described below.

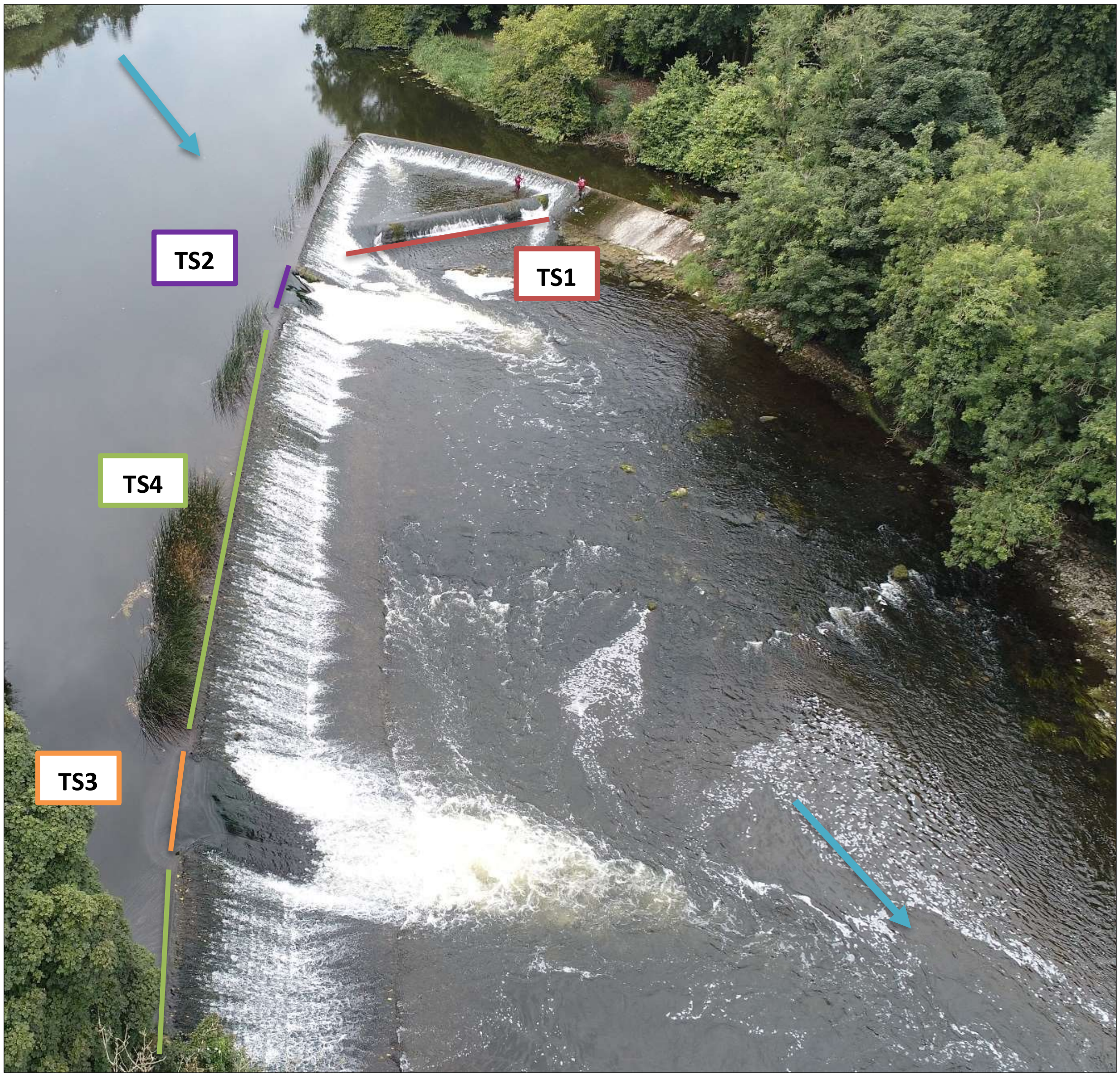


Figure 34. The four transversal sections of Carrickdexter Weir. Drone imagery taken 08/09/2021.

Transversal 1:

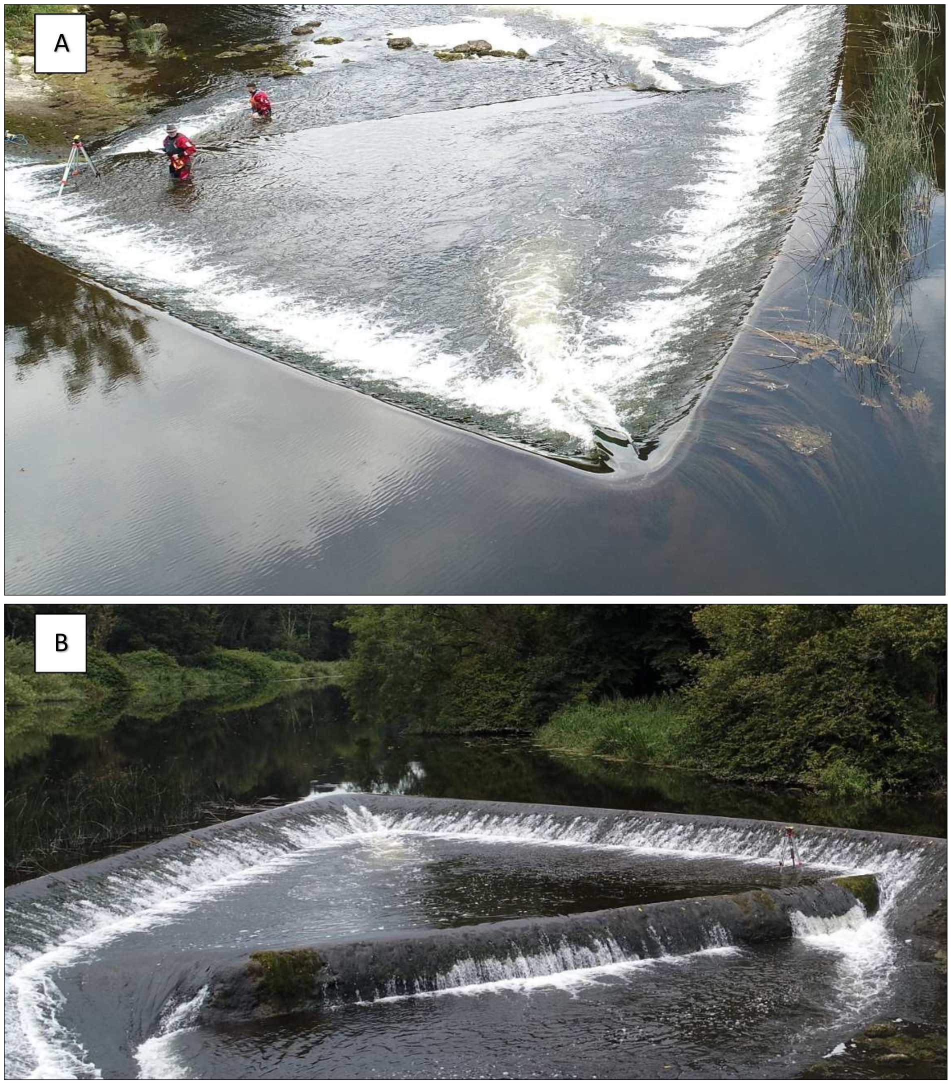


Figure 35. Transversal Section 1 from upstream (A) and downstream (B) perspectives.

In prevailing conditions, this transversal was a complete barrier to the upstream movement of juvenile eel and cyprinids (Figure 35). The velocity levels at the outlet completely barricaded the upstream environment from juvenile eel (score 0.0). For cyprinids, the step height (0.272m) represented an insurmountable jump barrier (score 0.0). The remaining upstream migratory species encountered a high impact partial barrier (score 0.3). Multiple factors compounded this score, including step water depth, the presence of a standing wave, and medium levels of turbulence. Downstream migrants were uninhibited. Higher flows could potentially improve the passage of adult salmonids by increasing step water depth. However, passage for other migratory species would likely remain unaltered.

Transversal 2:

Figure 36. Transversal Section 2.

In prevailing conditions, this transversal was a complete barrier to the upstream movement of all species (score 0.0). The midpoint velocities (≥3.8 m/s) made this section of the weir insurmountable. Additional obstacles included a slope of 38.85%, the presence of a standing wave, and high levels of turbulence (Figure 36). The crest velocities inhibited the downstream migration of cyprinids (score 0.3) and juvenile salmonids (score 0.6). However, the remaining downstream migrants traversed the section unhindered. Higher flows would be unlikely to improve passage of upstream migrants other than, potentially, adult salmonids.

Transversal 3:

Figure 37. Transversal Section 3.

Similarly to TS2, this transversal was a complete barrier to the upstream movement of all species (score 0.0) in prevailing conditions. Again, the midpoint velocities (≥3.6m/s) rendered the transversal insurmountable. Additional obstacles also mirrored TS2 and included a slope of 21.82%, the presence of a standing wave, and high levels of turbulence (Figure 37). A reprieve in crest velocities allowed for the unhindered passage of all downstream migrants (score 1.0). Higher flows would be unlikely to improve passage of upstream migrants other than, potentially, adult salmonids.

Transversal 4:

Figure 38. Transversal Section 4.

In prevailing conditions, this transversal was a complete barrier to the upstream movement of all species (score 0.0). Insufficient water depths (≤0.04m) at the crest, midpoint, and outlet of the weir entirely negated fish passage. Compounding factors hindering upstream migration included high levels of turbulence and 39.83% slope. Downstream migration for most species was also inhibited by limited water depths (Figure 38). Juvenile salmonids and adult eel encountered a high impact partial barrier (score 0.3). Adult salmonids and cyprinids were completely obstructed (score 0.0). However, due to low requirements, juvenile lamprey faced no barrier to downstream passage. Higher flows, and therefore increased depths, would likely improve passage for adult salmonids. The additional issues of slope and turbulence would block the remaining upstream migrants from availing of improvements to depth. Higher flows would likely completely alleviate obstacles to downstream passage and allow for unhindered movement of downstream migrants.

Passability Assessment for Site (Table 6)

On the day of survey, only transversal 1 facilitated limited upstream passage at Carrickdexter Weir. The remaining three transversals were complete barriers due to slope and high levels of turbulence, combined with either high velocities or low depths. The velocity and step height at transversal 1 represented a complete obstacle to juvenile eel and cyprinids respectively. Salmonids and adult eel encountered a high impact partial barrier and were the only species able to make even restricted passage at Carrickdexter Weir. Downstream migrants were primarily best supported by transversals 1 and 3. All species were able to traverse the weir unhindered in a downstream direction. Higher flows would have the potential to open new upstream passage routes for adult salmonids. However, passage for other upstream migratory species would likely continue unaltered.

Table 6: Final Passability Assessment for Carrickdexter Weir

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon	current conditions			✘		✘			
(AS)	high flows		✘			✘			
Adult Trout	current conditions			✘		✘			
(AT)	high flows		✘			✘			
Cyprinids	current conditions				✘	✘			
(C)	high flows				✘	✘			
Adult Lamprey	current conditions			✘					
(AL)	high flows			✘					
Juvenile Eel	current conditions				✘				
(JE)	high flows				✘				
Juvenile	current conditions			✘		✘			
Salmonids (JS)	high flows			✘		✘			
Juvenile	current conditions					✘			
Lamprey (JL)	high flows					✘			
Adult Eel	current conditions					✘			
(AE)	high flows					✘			

7. Dollardstown Weir

River: Boyne	Survey Date: 14/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 692780, 772053
River Water Body: 07_1835_80	Name of Structure: Dollardstown Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

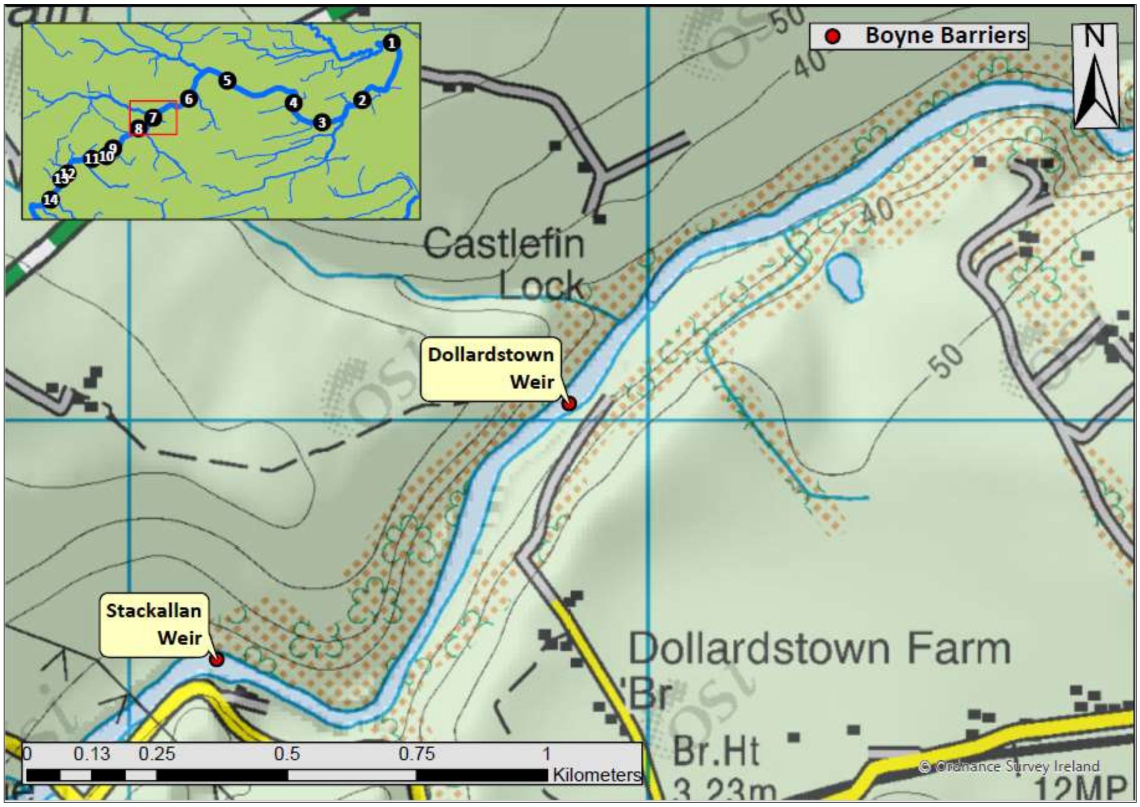
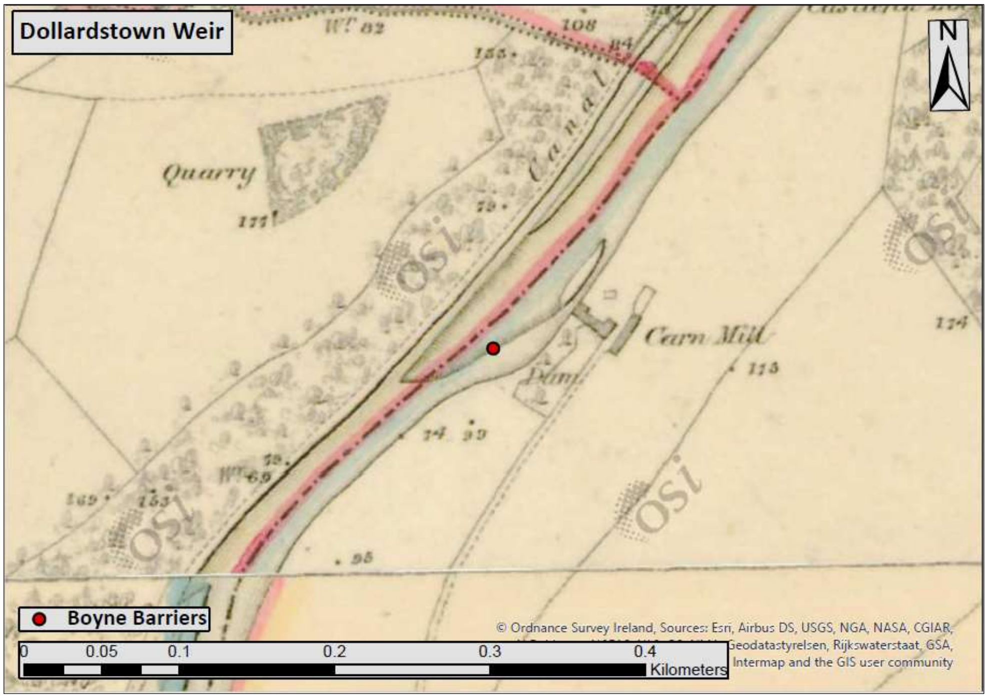


Figure 39. The location of Dollardstown Weir, Co. Meath.

Dollardstown Weir is located on the main stem of the River Boyne, Co. Meath (Figure 39). It is located 2.04 km upstream of Carrickdexter Weir and is approximately 17 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Dollardstown and Stackallan. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. On the historic 6" maps, a corn mill is located adjacent to the weir on the south bank (Figure 40). This mill is no longer displayed on the later 25" maps, suggesting that the weir may have become obsolete over a century ago. Dollardstown Weir is located on a stretch of river subject to a high probability of fluvial flooding with an AEP of 10% (OPW, 2019).



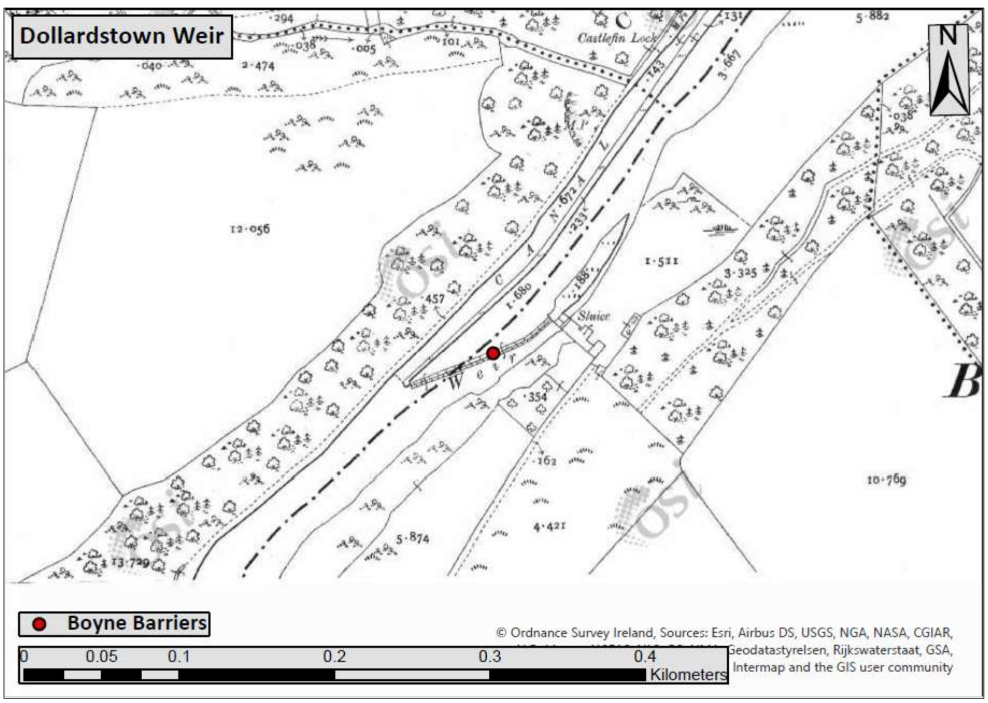


Figure 40. Location of Dollardstown Weir as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Blackcastle gauging station (07037) was 0.591 m. The hydraulic head height of the weir varied from 0.93 m at TS3 to 1.17 m at TS1. The total width of the barrier along the crest was an estimated 200 metres, not all of which was wetted. The width of the channel at this point was approximately 50 metres. This sloping crump weir with vertical elements presented four transversal sections for fish to attempt passage (Figure 41), which are described below. Transversal 4 was not fully surveyed due to health and safety concerns.

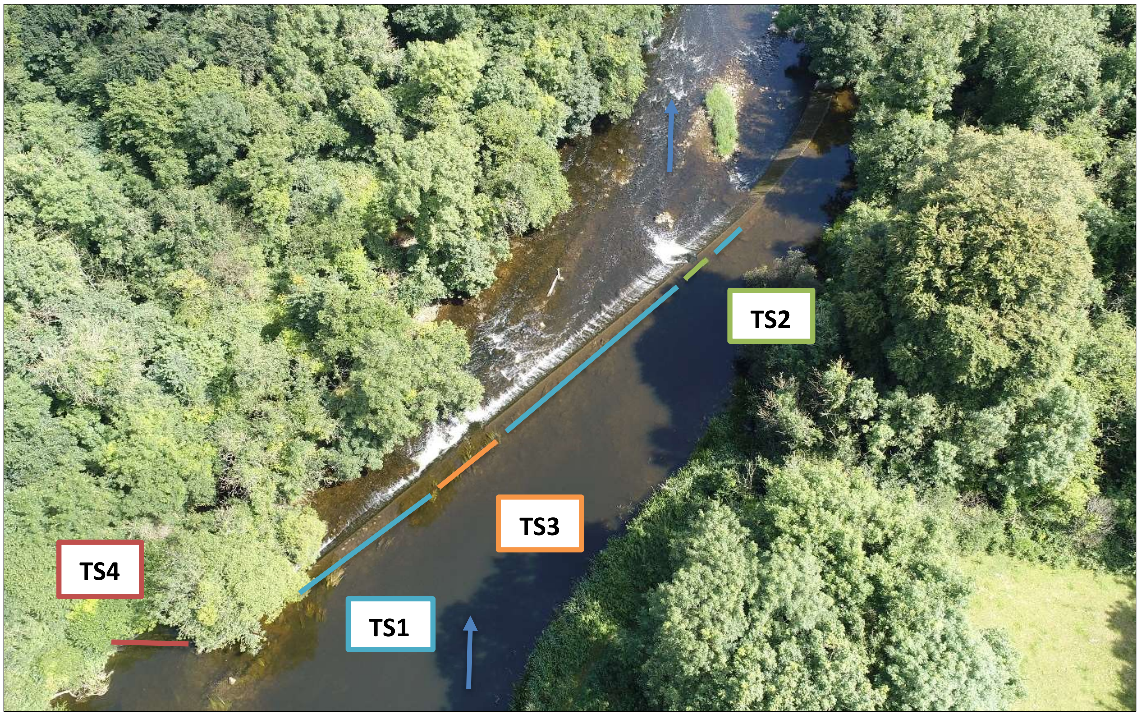


Figure 41. The four transversal sections of Dollardstown Weir. Drone imagery taken 14/07/2021.

Transversal 1:

Figure 42. Transversal Section 1.

In prevailing conditions, this transversal was a complete barrier to the upstream movement of all species (score 0.0), with the exception of juvenile eel (score 1.0). Insufficient water depth (≤0.03 m) at the outlet was the primary obstacle. A compounding factor hindering upstream migration was the 45% slope (Figure 42). As a climbing substrate was available, juvenile eel were capable of surmounting the structure. Downstream migration for most species was similarly inhibited by limited water depths. Juvenile salmonids and adult eel encountered a high impact partial barrier (score 0.3). Adult salmonids and cyprinids were completely obstructed (score 0.0). However, due to limited depth requirements, juvenile lamprey faced no barrier to downstream passage (score 1.0). Higher flows, and therefore increased depths, would likely improve passage for adult salmonids. The additional issues of slope and turbulence would limit the remaining upstream migrants from availing of improvements to depth. Higher flows would likely completely alleviate obstacles to downstream passage and allow for unimpeded movement of migrants in that direction.

Transversal 2:

Figure 43. Transversal Section 2.

In prevailing conditions, adult salmonids encountered a high impact partial barrier (score 0.3) at this transversal, allowing limited passability. All other upstream migrants encountered a complete barrier (score 0.0) to their movements. The primary hurdles were high outlet velocities (≥2.15 m/s) and low outlet depths (0.04 to 0.1 m) (Figure 43). Additional obstacles included a slope of 45% and the presence of a standing wave. Downstream migrants were able to traverse the section without restraint. Higher flows would be unlikely to improve passage of upstream migrants.

Transversal 3:

Figure 44. Transversal Section 3.

In prevailing conditions, this transversal represented a high impact partial barrier (score 0.3) for the upstream migration of adult salmonids and juvenile eel (Figure 44). Cyprinids, adult lamprey, and juvenile salmonids encountered a complete barrier (score 0.0). A variety of factors were responsible for the restrictions on passage. The hydraulic head height (0.93 m) was the primary obstacle for the latter three species. For adult salmonids, the most limiting factor was the low effective pool depth (0.5 m). Meanwhile, medium levels of turbulence checked the progress of juvenile eel. Downstream migrants encountered no obstacles to passage (score 1.0). Higher flows would have a limited effect on improving upstream passage. A greater pool depth in relation to a lowered hydraulic head height would increase the likelihood of adult salmonid passage. However, the jump barrier for the remaining species would remain in place unless substantially lowered. In addition, the increased turbulence associated with higher flows would further negate rather than facilitate the passage of upstream migrants.

Transversal 4:

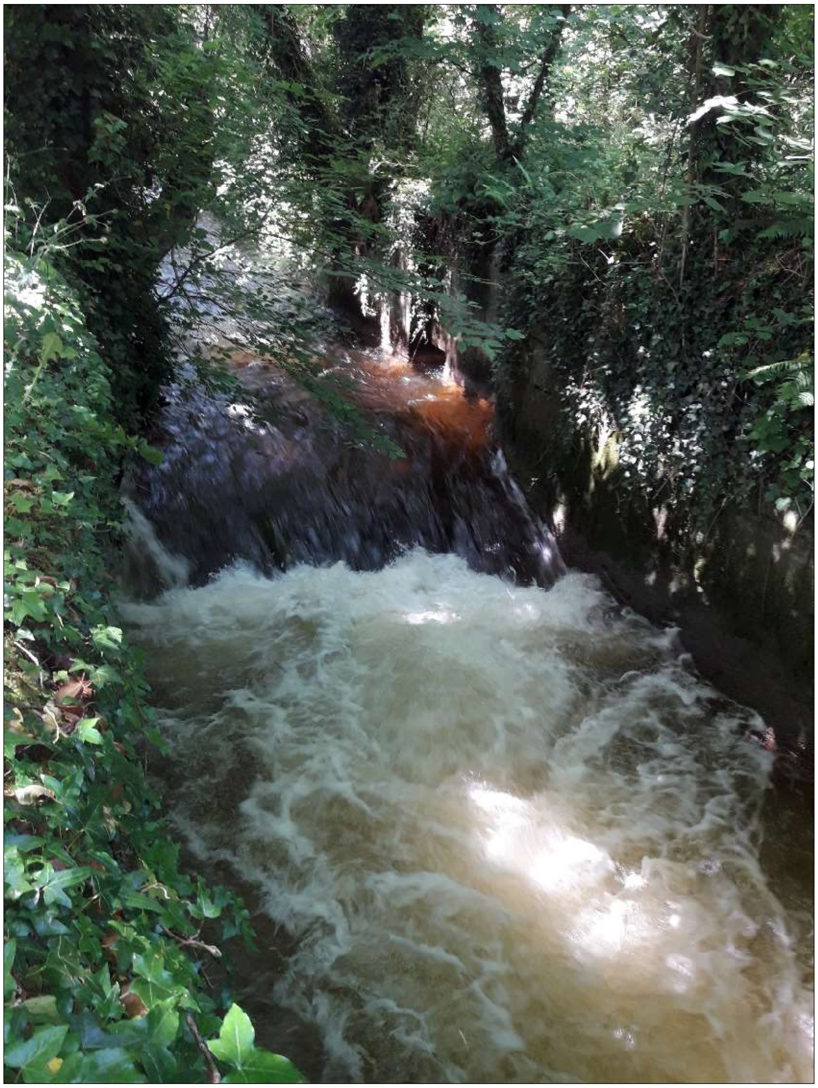


Figure 45. Vertical drop at transversal section 4.

In prevailing condition, this segment of the weir was unsuitable for assessment due to health and safety concerns. However, the observed standing wave and high levels of turbulence were sufficient to create a complete barrier (score 0.0) for the upstream migration of all species, with the exception of adult salmonids (Figure 45). Adult salmonids were presented with a high impact partial barrier (score 0.3). Potentially high velocity levels at the crest were likely to have encumbered downstream migration. Higher flows would be unlikely to improve passage as the funnelled flow of water would restrict any possible decreases in velocity levels.

Passability Assessment for Site (Table 7)

On the day of survey, Dollardstown Weir was a complete barrier (score 0.0) to the upstream migration of cyprinids, adult lamprey, and juvenile salmonids. Juvenile eel, however, could avail of two passage route options, transversals 1 and 3. Transversal 3 offered a limited chance of passage success, functioning as a high impact partial barrier. Transversal 1, in contrast, allowed the free movement of the species due to an available climbing substrate. The greatest choice of route options was afforded to adult salmonids. Three avenues were available to them, comprising of transversals 2, 3, and 4. However, all three were high impact partial barriers in prevailing conditions. A variety of elements were responsible for the limited upstream movement possible at Dollardstown Weir, including high levels of turbulence, high velocities, low depths, and a high percentage slope. Downstream migration was not inhibited to the same extent. Both transversals 2 and 3 offered no barrier to any downstream migrating species. Higher flows would have limited potential to improve upstream passage, primarily only facilitating enhanced migration for adult salmonids (Table 7).

Table 7: Final Passability Assessment for Dollardstown Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0	**No barrier** 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0
Adult Salmon (AS)	current conditions			X		X			
	high flows		X			X			
Adult Trout (AT)	current conditions			X		X			
	high flows		X			X			
Cyprinids (C)	current conditions				X	X			
	high flows				X	X			
Adult Lamprey (AL)	current conditions				X				
	high flows				X				
Juvenile Eel (JE)	current conditions	X							
	high flows	X							
Juvenile Salmonids (JS)	current conditions				X	X			
	high flows				X	X			
Juvenile Lamprey (JL)	current conditions					X			
	high flows					X			
Adult Eel (AE)	current conditions					X			
	high flows					X			

8. Stackallan Weir

River: Boyne	Survey Date: 7/09/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, G McManus
River Basin District: ERBD	Grid ref: 692102, 771561
River Water Body: 07_1834_52	Name of Structure: Stackallan Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

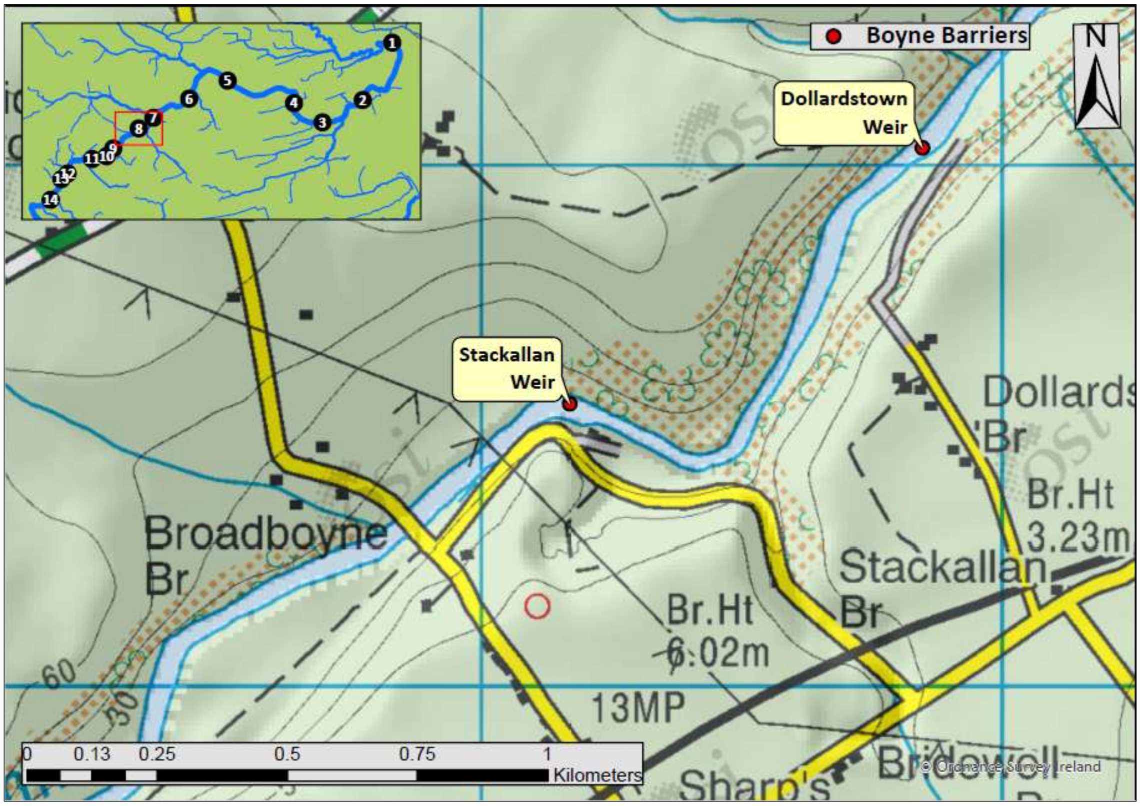


Figure 46. The location of Stackallan Weir, Co. Meath

Stackallan Weir is located on the main stem of the River Boyne, Co. Meath (Figure 46). It is located 1.04 km upstream of Dollardstown Weir and is approximately 18 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Ardmulchan and Stackallan. The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. On the historic 6" maps, a corn mill is located adjacent to the weir on the south bank (Figure 47). By the later 25" maps, the same building is referred to as a woollen mill, demonstrating a change of purpose. Both maps depict a site named "Lugaree" immediately upstream of the weir. Wilde (1849) describes the "ancient pagan remembrances and superstitions" associated with this site as continuing up until just before his time. This site was used during Lughnasa celebrations for the tradition of swimming horses (NMS, 2020). A horse and its rider swam through a deep section of river before sunrise in order to protect the animal from disease and fairies. As the river turns at this point, erosion would have naturally occurred, creating the required depth for the horse to be fully submerged. Stackallan Weir is located on a stretch of river subject to a high probability of fluvial flooding with an AEP of 10% (OPW, 2019). The weir and its upstream environment were subject to surface water flooding during the winter of 2015/2016 (OPW, 2019).

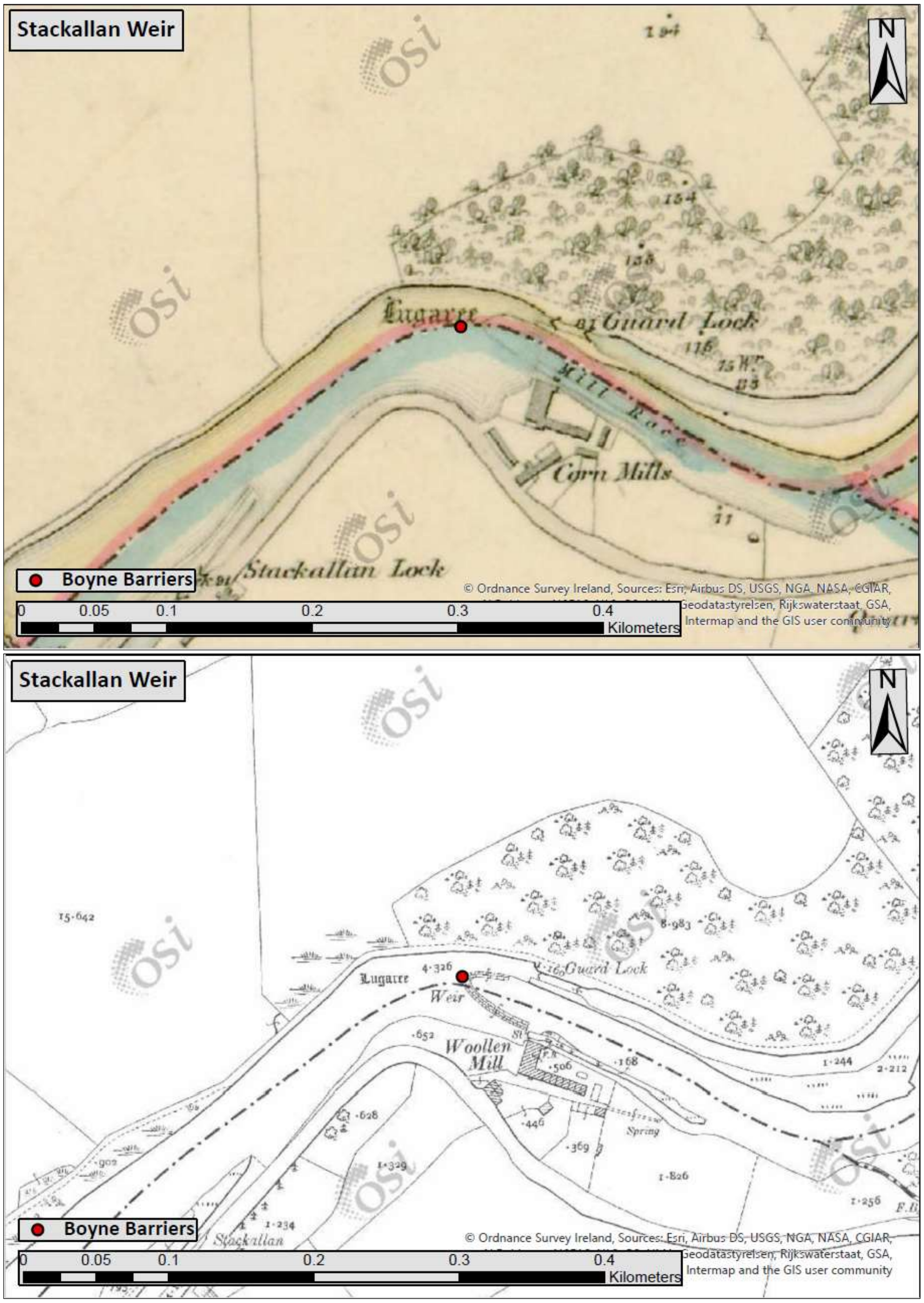


Figure 47. Location of Stackallan Weir as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Slane Castle gauging station (07012) was 0.575 m. The hydraulic head height of this horse-shoe shaped weir was 1.975 m. The total width of the barrier along the crest was 95 metres, of which 15 metres were wetted. The width of the channel at this point was 40 metres. This sloping weir with vertical elements presented four transversal sections for fish to attempt passage (Figure 48), which are described below. Transversals 3 and 4 were not fully surveyed due to health and safety concerns.

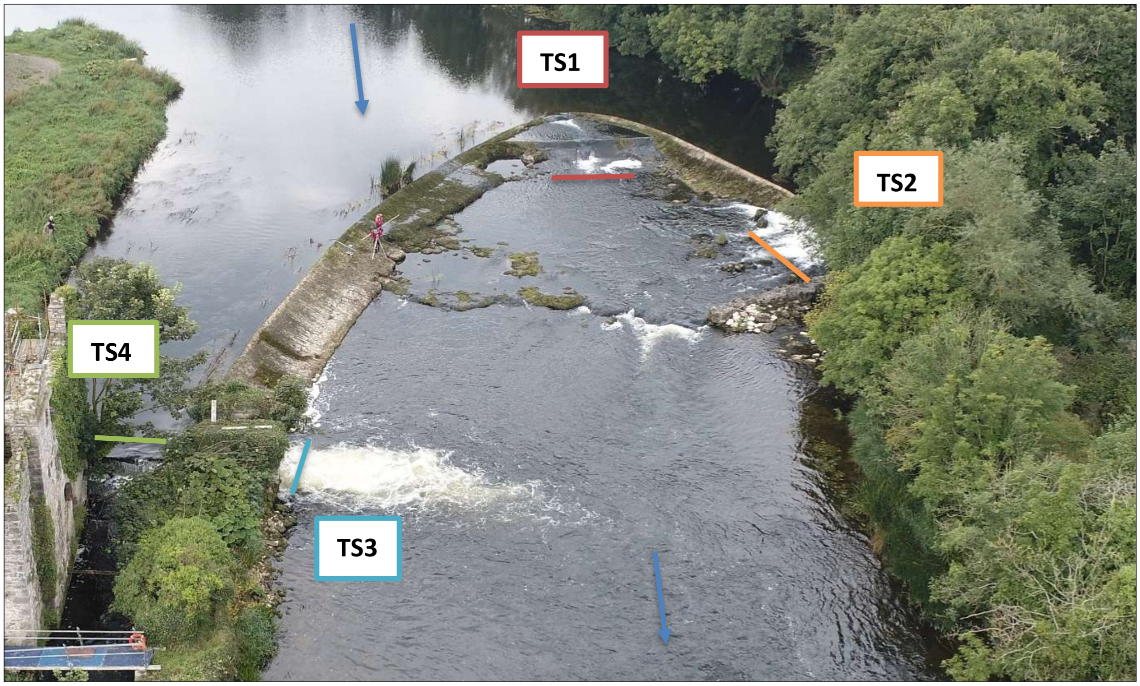


Figure 48. The four transversal sections of Stackallan Weir. Drone imagery taken 08/09/2021.

Transversal 1:

Figure 49. Transversal Section 1.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream movement of all species except juvenile eel. The primary obstacle was created by low depths, particularly at the outlet (≤0.05 m) (Figure 49). An additional obstruction to passage was the slope (24.09%). Juvenile eel were able to surmount the transversal via a climbing substrate, and thus encountered no barrier (score 1.0) to their upstream migration. All downstream migrants were unimpeded in their movements (score 1.0). Higher flows would be likely to improve the passage of adult salmonids due to increased water depth. However, passage for juvenile eel would be likely to deteriorate as the climbing substrate would be drowned in the increased flow of water over the weir. The passage of other migratory species would likely remain unaltered.

Transversal 2:

Figure 50. Transversal Section 2.

In prevailing conditions, this transversal was a complete barrier (score 0.0) to the upstream movement of all species. The primary obstacles to passage were the hydraulic head height (1.975m) and the high levels of turbulence (Figure 50). All downstream migrants were unimpeded in their movements (score 1.0). Higher flows have the potential to marginally improve the upstream passage of adult salmon by decreasing the hydraulic head height. However, passage for other migratory species would likely remain unaltered as turbulence levels would be maintained, if not increased, and the reduction in hydraulic head height would have to be substantially greater than what is surmountable for adult salmon.

Transversal 3:

Figure 51. Transversal Section 3 from the outlet (left) and the crest (right).

In prevailing condition, velocity and water depth could not be measured at this transversal due to health and safety concerns (Figure 51). However, the standing wave, very high levels of turbulence, and hydraulic head height (1.975 m) were sufficient to create a complete barrier (score 0.0) for the upstream migration of all species. Potentially high velocity levels at the crest were likely to have encumbered downstream migration. Higher flows would be unlikely to improve passage as the funnelled flow of water would maintain velocity levels and turbulence.

Transversal 4:

Figure 52. Transversal Section 4, perspective from the crest (left) and from downstream (right).

In prevailing condition, this segment of the weir was unsuitable for assessment due to health and safety concerns (Figure 52). However, the observed high levels of turbulence and the hydraulic head height (1.95 m) were sufficient to create a complete barrier (score 0.0) for the upstream migration of all species. Downstream migrants were unhindered as far as can be estimated with the restricted measurements. Higher flows would be unlikely to improve passage for any species.

Passability Assessment for Site (Table 8)

On the day of survey, Stackallan Weir was a complete barrier (score 0.0) to the upstream migration of all species except juvenile eel. Passage was predominantly hindered by high turbulence levels and the hydraulic head height at transversals 2, 3, and 4. Meanwhile, low depths and a slope of 24.09% were the limiting factors at transversal 1. Downstream migrants were unimpeded as a result of passage routes available at transversals 1 and 2. Higher flows would be likely to improve passage for adult salmonids but would simultaneously diminish passability for juvenile eel.

Table 8: Final Passability Assessment for Stackallan Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier	Partial barrier Low impact	Partial barrier High impact	Complete barrier	No barrier	Partial barrier Low impact	Partial barrier High impact	Complete barrier
		1	0.6	0.3	0.0	1	0.6	0.3	0.0
Adult Salmon	current conditions				✗	✗			
(AS)	high flows		✗			✗			
Adult Trout	current conditions				✗	✗			
(AT)	high flows		✗			✗			
Cyprinids	current conditions				✗	✗			
(C)	high flows				✗	✗			
Adult Lamprey	current conditions				✗				
(AL)	high flows				✗				
Juvenile Eel	current conditions	✗							
(JE)	high flows				✗				
Juvenile	current conditions				✗	✗			
Salmonids (JS)	high flows				✗	✗			
Juvenile	current conditions					✗			
Lamprey (JL)	high flows					✗			
Adult Eel	current conditions					✗			
(AE)	high flows					✗			

9. Ardmulchan Weir 1

River: Boyne	Survey Date: 13/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 690986, 770621
River Water Body: 07_1490_46	Name of Structure: Ardmulchan Weir 1
Owner:	IFI Analyst: R Donovan, A O'Connell

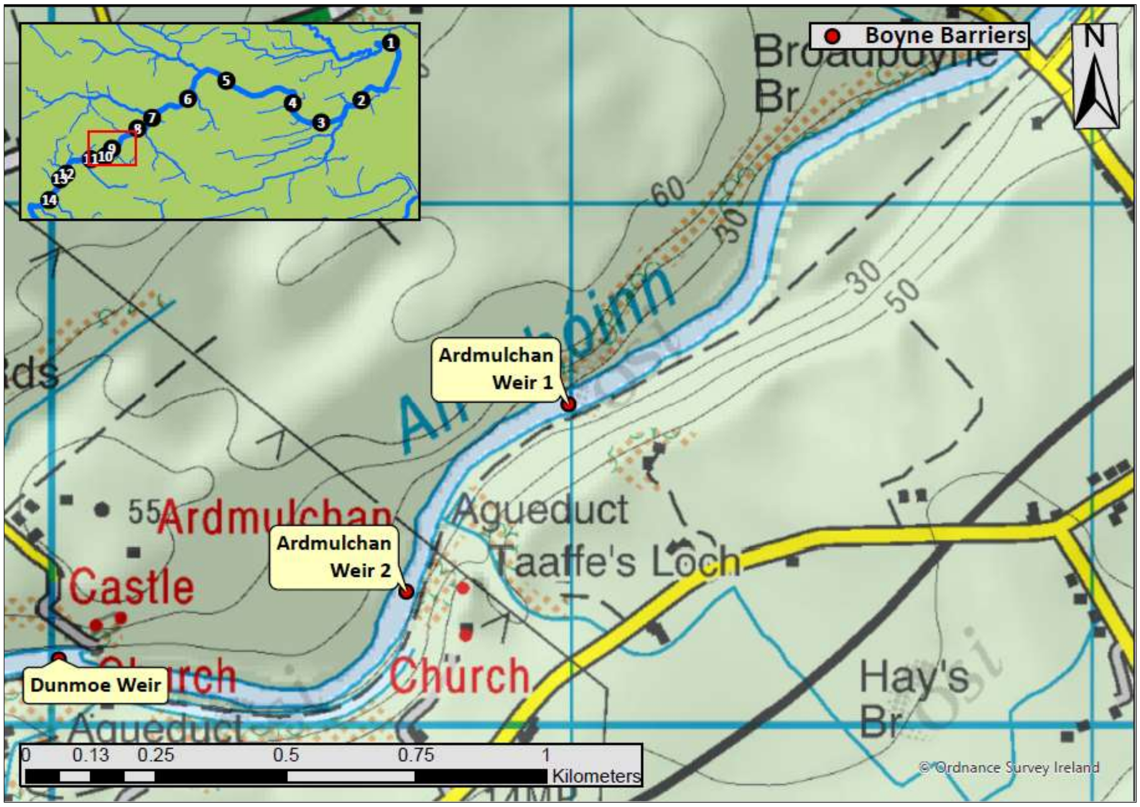
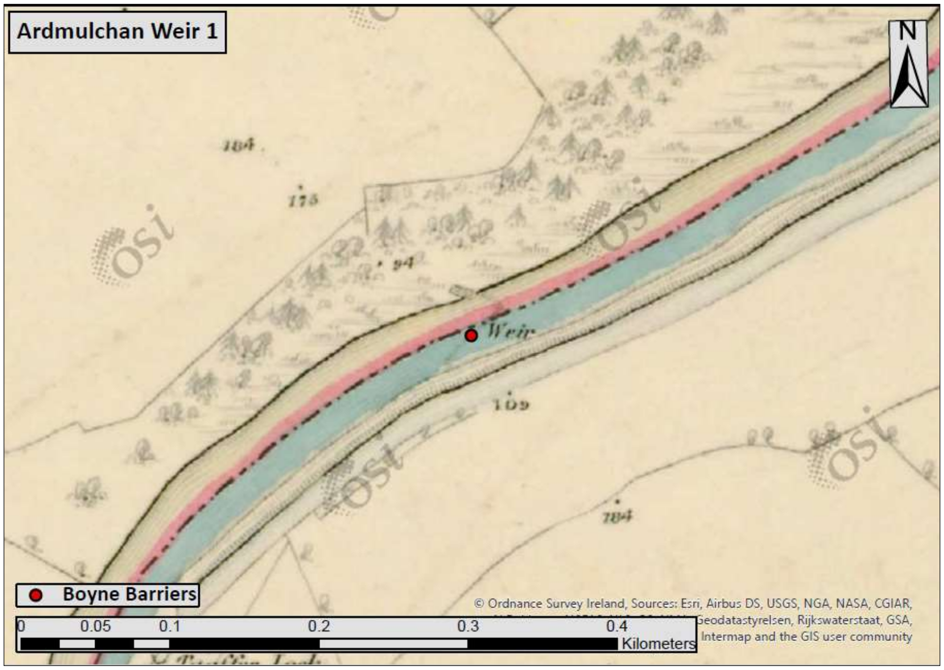


Figure 53. The location of Ardmulchan Weir 1, Co. Meath.

Ardmulchan Weir 1 is located on the main stem of the River Boyne, Co. Meath (Figure 53). It is located 1.51 km upstream of Stackallan Weir and is approximately 19.5 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Ardmulchan (south bank) and Dunmoe (north bank). The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. A weir is depicted in the current location of Ardmulchan 1 on both the historic 6" and 25" maps. However, the shape of the structure is inverted on the 6" map, with the point facing downstream rather than upstream (Figure 54). The weir illustrated on the 25" map is true to its current form. Also on the latter historic maps, the north bank of the weir is shown as "Liable to Flood". The area surrounding Ardmulchan Weir 1 remains subject to a high probability of fluvial flooding with an AEP of 10% (OPW, 2019). The environment experienced surface water flooding during the winter of 2015/2016 (OPW, 2019).



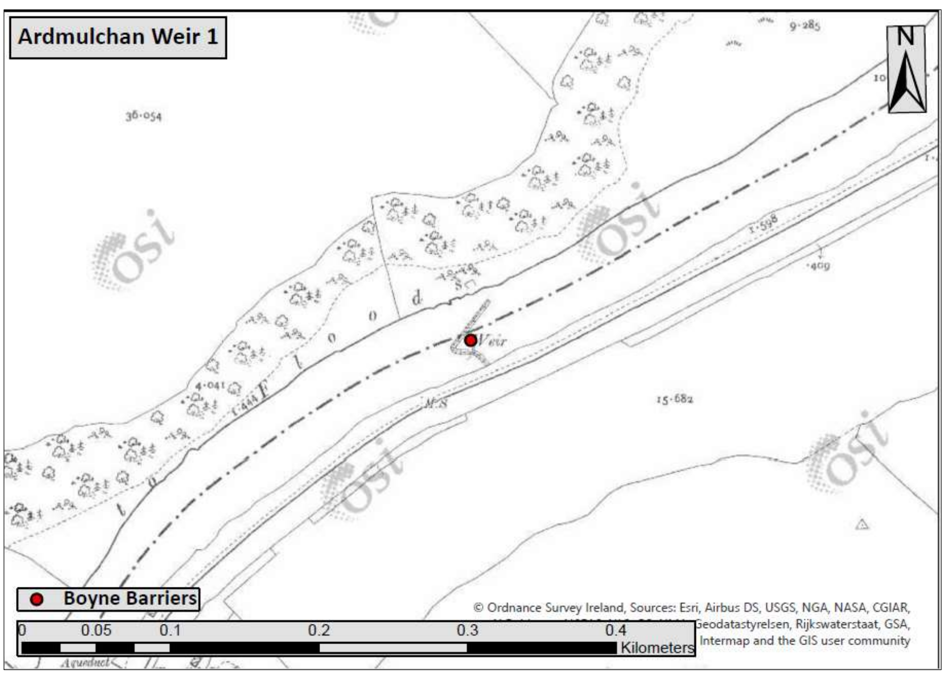


Figure 54. Location of Ardmulchan Weir 1 as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Blackcastle gauging station (07037) was 0.389 m. The hydraulic head height of the weir was 0.58 m. The total width of the barrier along the crest was 74 metres, of which 25 metres were wetted. The width of the channel at this point was 48 metres. This sloping weir presented two transversal sections for fish to attempt passage (Figure 55), which are described below.

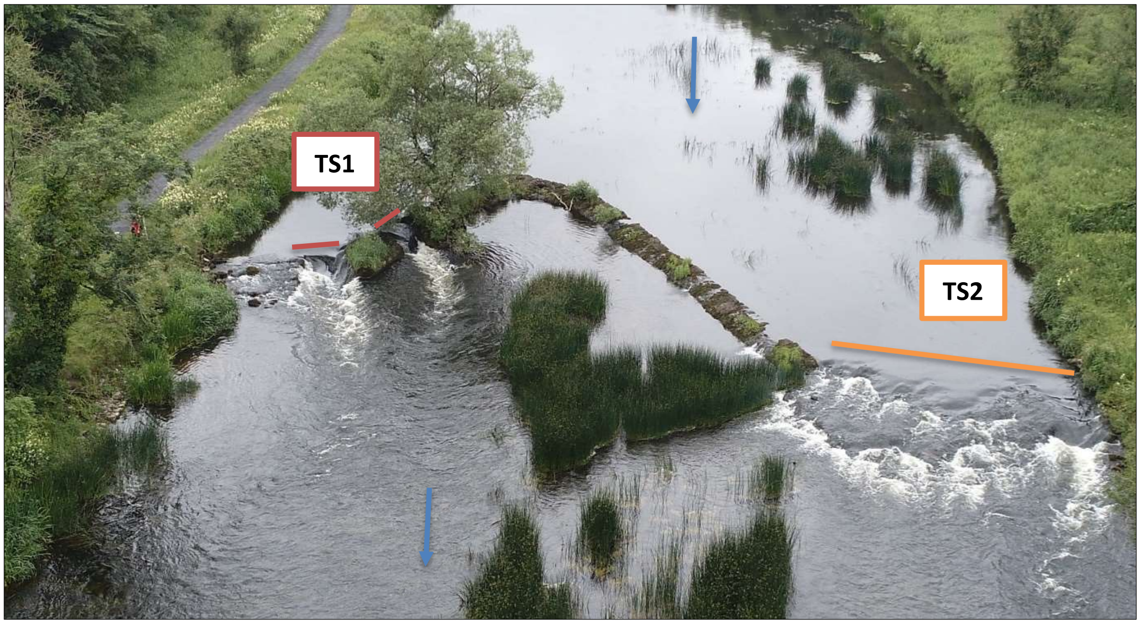


Figure 55. The two transversal sections of Ardmulchan Weir 1. Drone imagery taken 13/07/2021.

Transversal 1:

Figure 56. Transversal Section 1.

In prevailing conditions, this transversal presented no barrier (score 1.0) to the upstream movement of adult salmonids and juvenile eel (Figure 56). Cyprinids, adult lamprey, and juvenile salmonids encountered a low impact partial barrier (score 0.6) caused by the effective length (5.8 m). Juvenile eel were able to circumnavigate the transversal via a climbing substrate. Downstream migrants were unimpeded in their movements (score 1.0). Higher flows would be unlikely to alter passage.

Transversal 2:

Figure 57. Transversal Section 2.

In prevailing conditions, this transversal presented a high impact partial barrier (score 0.3) to the upstream movement of all species except adult salmonids (Figure 57). Adult salmonids encountered a low impact partial barrier (score 0.6). The primary obstacle was created by medium levels of turbulence. The effective length (9 m) was a compounding limiting factor, particularly for cyprinids and juvenile eel. Downstream migrants were unimpeded in their movements (score 1.0). Higher flows would have the potential to improve passage for salmonids and adult lamprey.

Passability Assessment for Site (Table 9)

On the day of survey, Ardmulchan Weir 1 facilitated the upstream migration of all species. Adult salmonids and juvenile eel encountered no barrier (score 1.0), while the remaining species were met with a low impact partial barrier (score 0.6). Transversal 1 provided a better passage route than transversal 2. Effective length was a hindrance to upstream passage common to both options. However, turbulence was the primary obstacle at transversal 2. Downstream migrants were unobstructed at either transversal. Higher flows would be unlikely to alter passage.

Table 9: Final Passability Assessment for Ardmulchan Weir 1.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions	✘				✘			
	high flows	✘				✘			
Adult Trout (AT)	current conditions	✘				✘			
	high flows	✘				✘			
Cyprinids (C)	current conditions		✘			✘			
	high flows		✘			✘			
Adult Lamprey (AL)	current conditions		✘						
	high flows		✘						
Juvenile Eel (JE)	current conditions	✘							
	high flows	✘							
Juvenile Salmonids (JS)	current conditions		✘			✘			
	high flows		✘			✘			
Juvenile Lamprey (JL)	current conditions					✘			
	high flows					✘			
Adult Eel (AE)	current conditions					✘			
	high flows					✘			

10. Ardmulchan Weir 2

River: Boyne	Survey Date: 13/07/2021
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain
River Basin District: ERBD	Grid ref: 690615, 770274
River Water Body: 07_1494_75	Name of Structure: Ardmulchan Weir 2
Owner:	IFI Analyst: R Donovan, A O'Connell

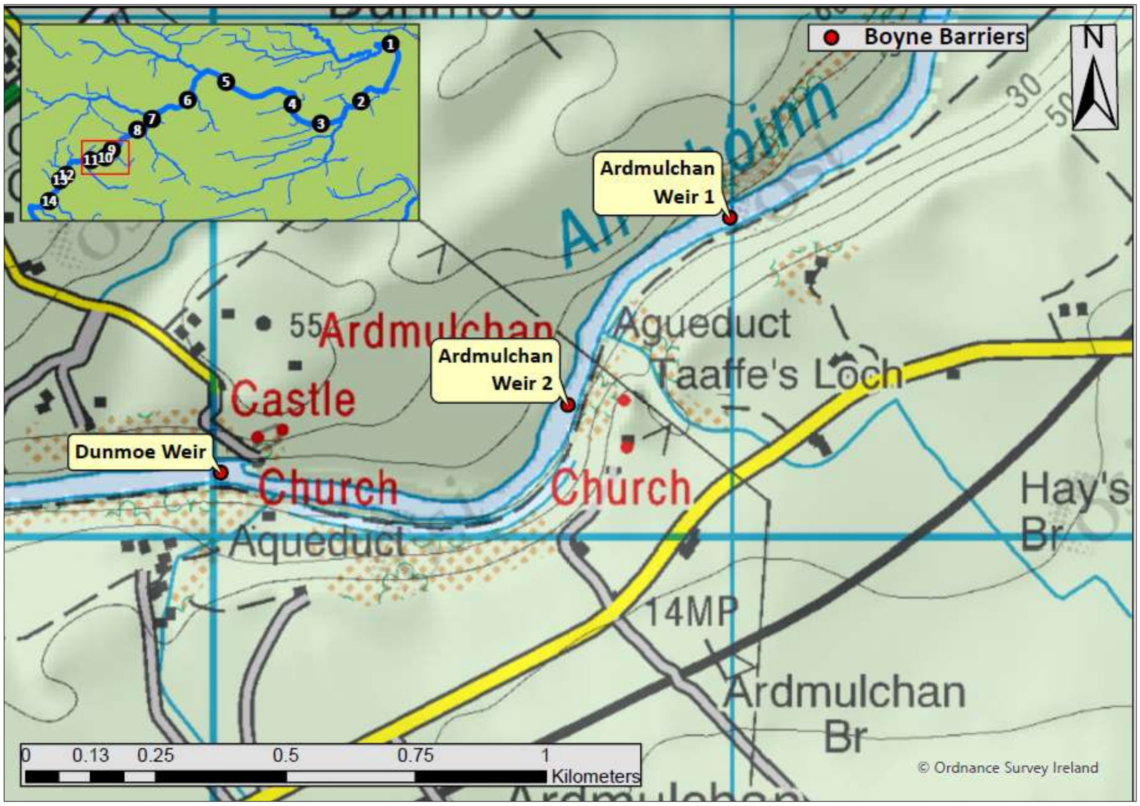


Figure 58. The location of Ardmulchan Weir 2, Co. Meath.

Ardmulchan Weir 2 is located on the main stem of the River Boyne, Co. Meath (Figure 58). It is situated 0.55 km upstream of Ardmulchan Weir 1 and is approximately 20 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Ardmulchan (south bank) and Dunmoe (north bank). The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. The historic 6" map depicts a church and fort on the south bank of the weir, in the Ardmulchan townland. The later historic 25" map, describes the church as "in ruins" (Figure 59). Both the fort and church are from the late 12th/early 13th century (NMS, 2020). Immediately upstream of the weir experienced surface water flooding during the winter of 2015/2016 (OPW, 2019).

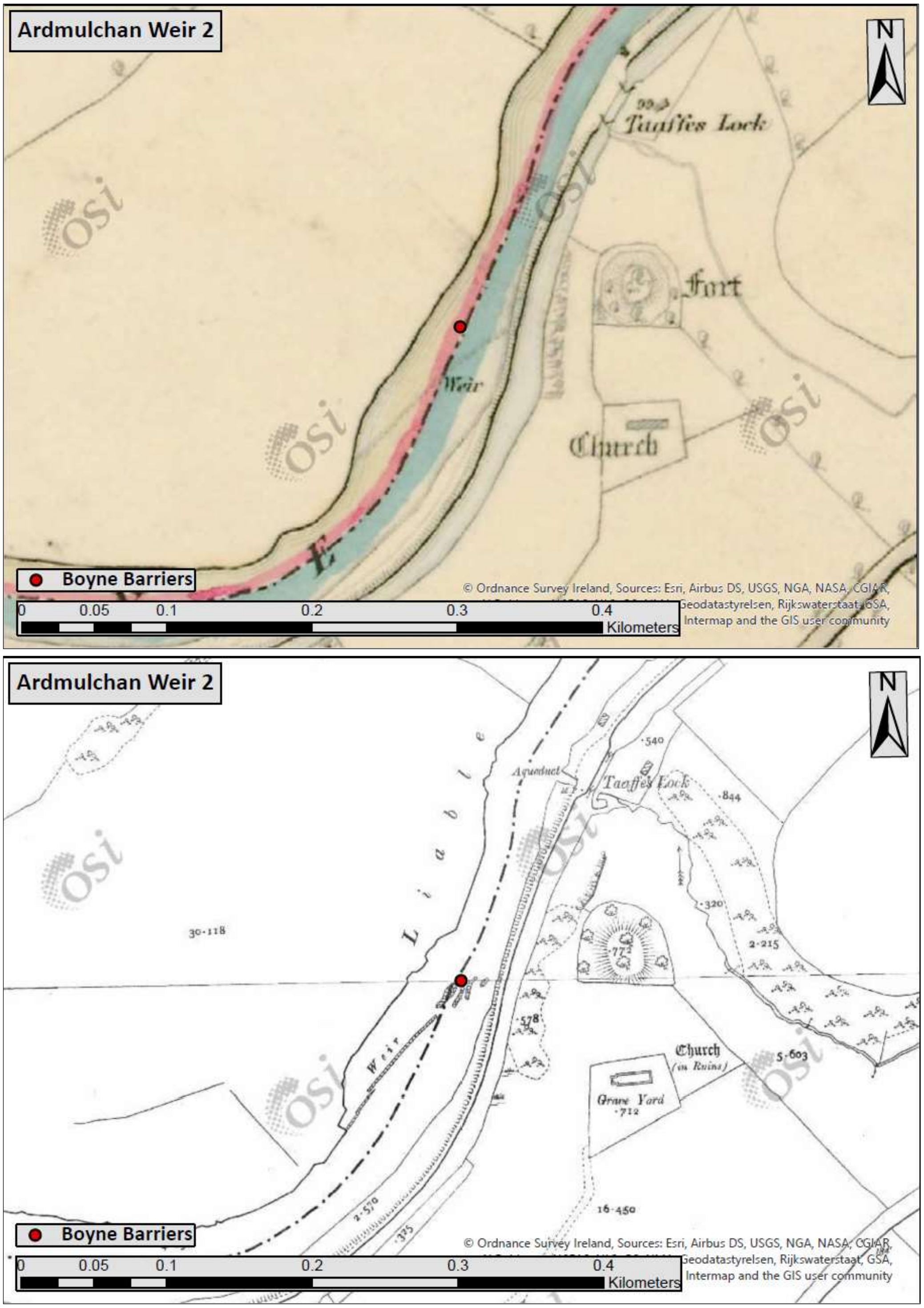


Figure 59. Location of Ardmulchan Weir 2 as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Blackcastle gauging station (07037) was 0.389 m. The hydraulic head height of the weir was 0.62 m. The total width of the barrier along the crest was 93 metres, of which 35 metres were wetted. The width of the channel at this point was 49 metres. This sloping weir presented two transversal sections for fish to attempt passage (Figure 60), which are described below.

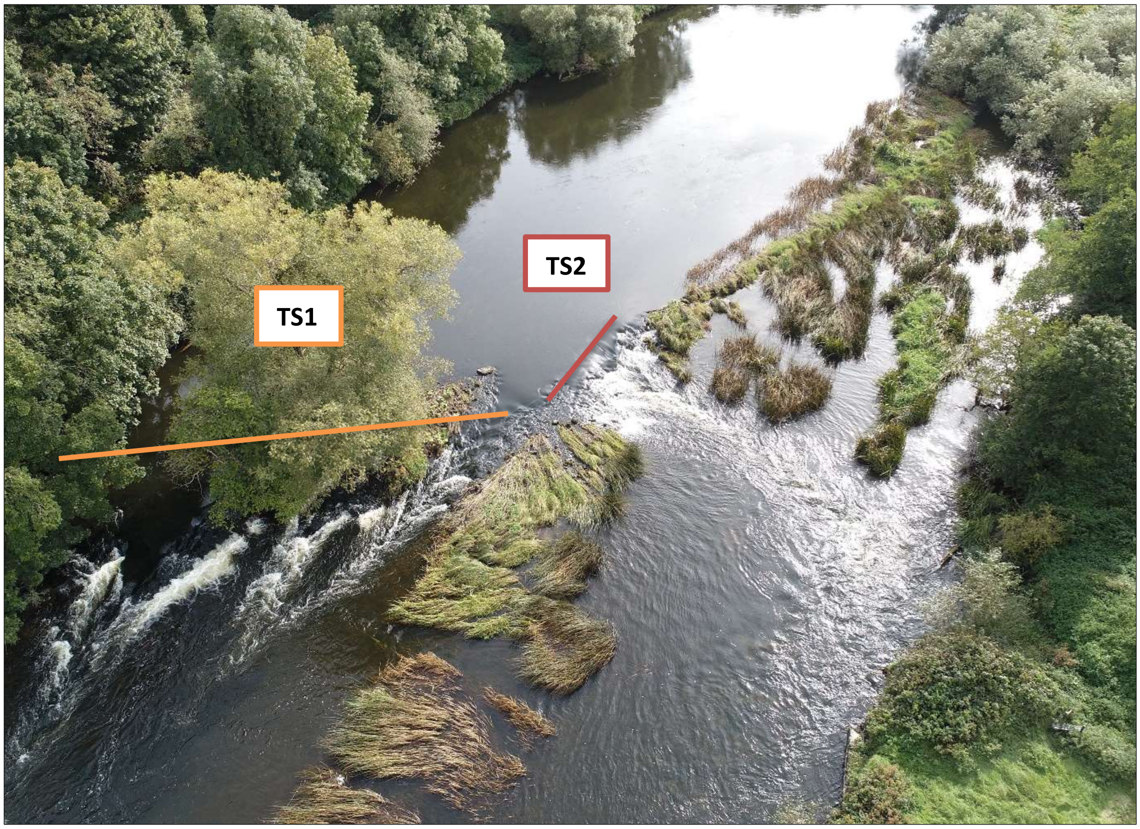


Figure 60. The two transversal sections of Ardmulchan Weir 2. Drone imagery taken 29/09/2020.

Transversal 1:

Figure 61. Transversal Section 1.

In prevailing conditions, this transversal represented a barrier, to differing extents, for all upstream migrants except juvenile eel (Figure 61). Adult salmonids encountered a low impact partial barrier (score 0.6). Cyprinids, adult lamprey, and juvenile salmonids were faced with a high impact partial barrier (score 0.3). Juvenile eel, however, were able to circumnavigate the structure via a climbing substrate, and thus were unimpeded in their migration (score 1.0). The primary obstacles to upstream passage were the effective length (11 m) and the medium levels of turbulence. Downstream migrants were unobstructed in their movements (score 1.0). Higher flows would be unlikely to alter passage.

Transversal 2:

Figure 62. Transversal Section 2.

In prevailing conditions, this transversal represented a high impact partial barrier (score 0.3) to all upstream migrants except juvenile eel (Figure 62). Juvenile eel were able to circumnavigate the structure via a climbing substrate, and thus were unimpeded in their migration (score 1.0). The primary obstacles to upstream passage were the presence of a standing wave and medium levels of turbulence. Downstream migrants were unobstructed in their movements (score 1.0). Higher flows would be unlikely to alter passage.

Passability Assessment for Site (Table 10)

On the day of survey, Ardmulchan Weir 2 facilitated the upstream migration of all species, albeit to varying degrees. Juvenile eel encountered no barrier (score 1.0), adult salmonids faced a low impact partial barrier (score 0.6), and the remaining species were met with a high impact partial barrier (score 0.3). Turbulence was a common factor inhibiting upstream progress at both transversals. Effective length, and the presence of a standing wave were additional obstacles at transversals 1 and 2 respectively. Downstream migrants were unobstructed at either transversal. Higher flows would be unlikely to alter passage.

Table 10: Final Passability Assessment for Ardmulchan Weir 2.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions		X			X			
	high flows		X			X			
Adult Trout (AT)	current conditions		X			X			
	high flows		X			X			
Cyprinids (C)	current conditions			X		X			
	high flows			X		X			
Adult Lamprey (AL)	current conditions			X					
	high flows			X					
Juvenile Eel (JE)	current conditions	X							
	high flows	X							
Juvenile Salmonids (JS)	current conditions			X		X			
	high flows			X		X			
Juvenile Lamprey (JL)	current conditions					X			
	high flows					X			
Adult Eel (AE)	current conditions					X			
	high flows					X			

11. Dunmoe Weir

River: Boyne	Survey Date: 22/09/2020
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain, J Ryan
River Basin District: ERBD	Grid ref: 689915,770111
River Water Body: 07_1834_54	Name of Structure: Dunmoe Weir
Owner:	IFI Analyst: R Donovan, A O'Connell

Figure 63. The location of Dunmoe Weir, Co. Meath.

Dunmoe Weir is located on the main stem of the River Boyne, Co. Meath (Figure 63). It is situated 0.80 km upstream of Ardmulchan Weir 2 and is approximately 21 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Ardmulchan (south bank) and Dunmoe (north bank). The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. The historic 6" map depicts a church, Dunmoe Castle, and a corn mill on the north bank of the weir (Figure 64). The south bank, on the same map, hosts a quarry. Changes on the later historic 25" map include the church and Dunmoe Castle being described as "in ruins", and a quarry on the north bank rather than the south. In 1640, the Parish of Dunmoe was owned by Thomas Darcy and contained "a Castle, a Church, a Mill, an Orchard and a fishing weare" (Simington, 1940). The area surrounding Dunmoe Weir has a high probability of fluvial flooding with an AEP of 10% (OPW, 2019). The environment experienced surface water flooding during the winter of 2015/2016 (OPW, 2019).

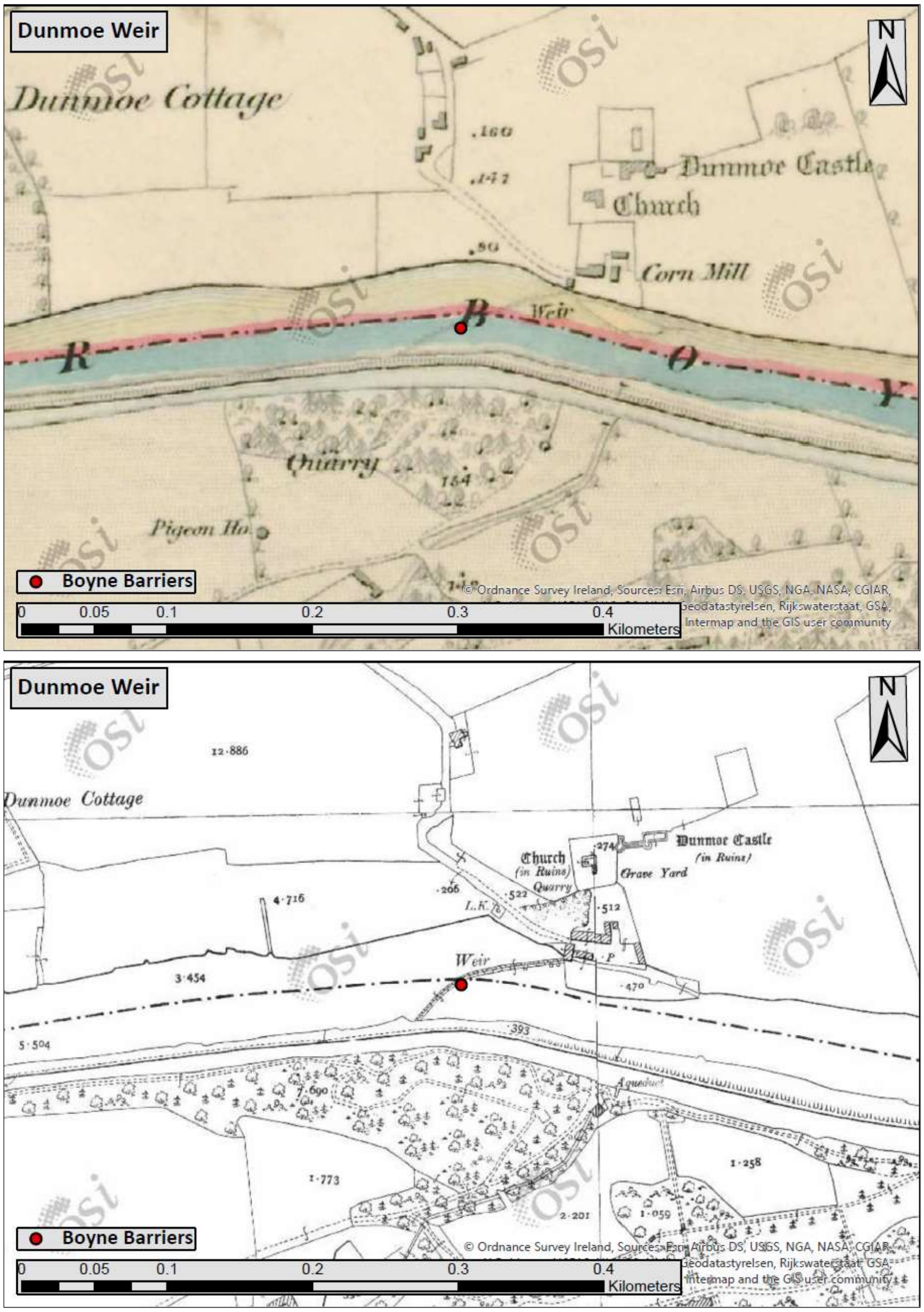


Figure 64. Location of Dunmoe Weir as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Navan Weir gauging station (07009) was 0.717 m. The hydraulic head height of the weir was 0.995 m. The total width of the barrier along the crest was 83 metres, of which 60 metres were wetted. The width of the channel at this point was 51 metres. This sloping weir presented three transversal sections for fish to attempt passage (Figure 65), which are described below.

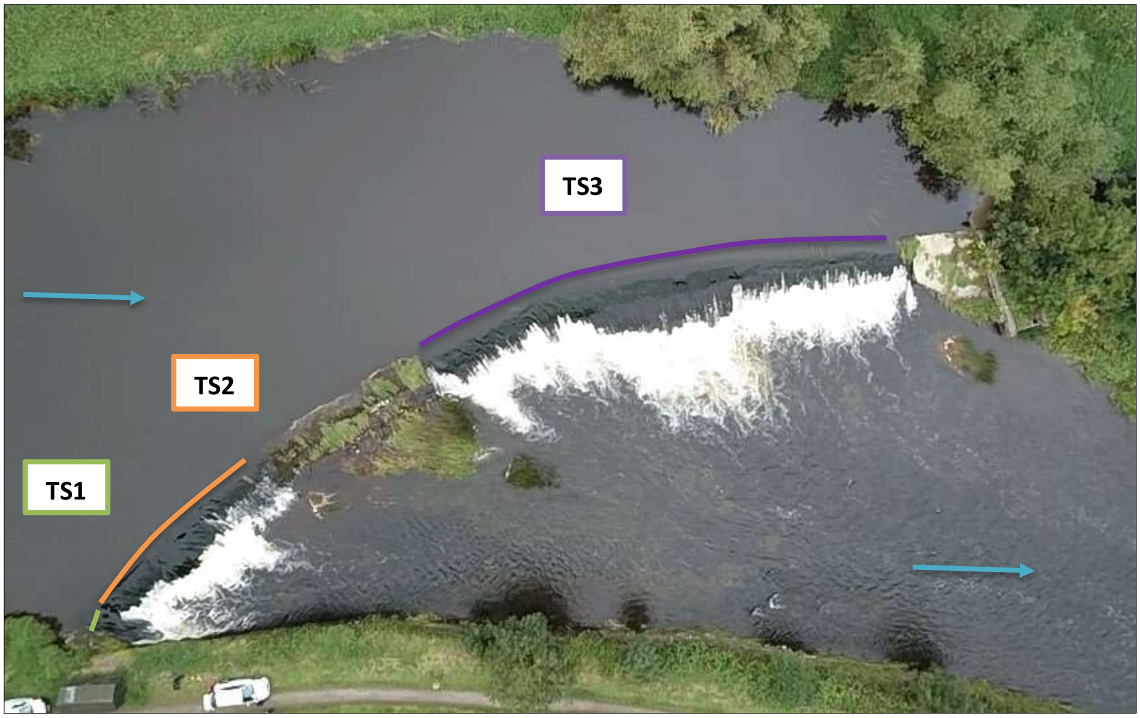


Figure 65. The three transversal sections of Dunmoe Weir. Drone imagery taken 22/09/2020.

Transversal 1:

Figure 66. Transversal Section 1.

In prevailing conditions, this transversal represented a barrier, to differing extents, for all upstream migrants except juvenile eel (Figure 66). Salmonids and adult lamprey encountered a high impact partial barrier (score 0.3), while cyprinids were obstructed completely (score 0.0). Juvenile eel, however, were able to circumnavigate the structure via a climbing substrate, and thus were unimpeded in their migration (score 1.0). The primary obstacles to upstream passage were the lack of effective resting locations, the medium levels of turbulence, the 18.9% slope, and the crest velocities at 60% depth (2.19 to 3.21 m/s). Downstream migrants, with the exception of juvenile lamprey and adult eel, were also inhibited by crest velocities. For adult salmonids velocities represented a low impact partial barrier (score 0.6). Juvenile salmonids fared worse, encountering a high impact partial barrier (score 0.3). Meanwhile, the movement of cyprinids was completely curtailed (score 0.0). Higher flows would be unlikely to improve passage for most species attempting to traverse this segment of weir. However, adult salmonids could potentially benefit from elevated flows.

Transversal 2:

Figure 67. Transversal Section 2.

In prevailing conditions, this transversal represented a complete barrier (score 0.0) for all upstream migrants except juvenile eel and adult salmonids. Adult salmonids encountered a high impact partial barrier (score 0.3). Juvenile eel, however, were able to circumnavigate the structure via a climbing substrate, and thus were unimpeded in their migration (score 1.0). There were multiple factors limiting upstream migration. These factors included the 24.27% slope, a lack of effective resting locations, high levels of turbulence, and the presence of a standing wave (Figure 67). Downstream migrants had uninhibited passage (score 1.0). Higher flows would be unlikely to improve passage. In fact, as elevated water levels could potentially drown the climbing substrate, the passage of juvenile eels would deteriorate.

Transversal 3:

Figure 68. Transversal Section 3.

In prevailing conditions, this transversal represented a complete barrier (score 0.0) for all upstream migrants except juvenile eel. Juvenile eel were able to circumnavigate the structure via a climbing substrate, and thus were unimpeded in their migration (score 1.0). There were multiple factors limiting upstream migration. The most detrimental of these factors included the 20.31% slope, high levels of turbulence, low outlet water depths (≤0.05 m), and high outlet velocities (≥3.3 m/s) (Figure 68). In contrast to their upstream migrating counterparts, downstream migrants had uninhibited passage (score 1.0). Higher flows would be unlikely to improve passage.

Passability Assessment for Site (Table 11)

On the day of survey, Dunmoe Weir was predominantly a high impact partial barrier (score 0.3) for species attempting upstream migration. Cyprinids, however, were completely obstructed by this structure (score 0.0). In contrast, juvenile eel encountered no barrier (score 1.0). Climbing substrates allowed the species to bypass the water flow at each transversal. Common factors inhibiting upstream movement included slope, lack of effective resting locations, the presence of a standing wave, levels of turbulence, and high velocity levels. Transversal 1 best facilitated upstream passage, while downstream passage was most viable at transversals 2 and 3. Downstream migrants were unobstructed at either transversal. Higher flows would be unlikely to improve passage for species other than adult salmonids.

Table 11: Final Passability Assessment for Dunmoe Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0	**No barrier** 1	**Partial barrier Low impact** 0.6	**Partial barrier High impact** 0.3	**Complete barrier** 0.0
Adult Salmon (AS)	current conditions			✘		✘			
	high flows		✘			✘			
Adult Trout (AT)	current conditions			✘		✘			
	high flows		✘			✘			
Cyprinids (C)	current conditions				✘	✘			
	high flows				✘	✘			
Adult Lamprey (AL)	current conditions			✘					
	high flows			✘					
Juvenile Eel (JE)	current conditions	✘							
	high flows	✘							
Juvenile Salmonids (JS)	current conditions			✘		✘			
	high flows			✘		✘			
Juvenile Lamprey (JL)	current conditions					✘			
	high flows					✘			
Adult Eel (AE)	current conditions					✘			
	high flows					✘			

12. Blackcastle Demesne Weir 1

River: Boyne	Survey Date: 22/09/2020
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain, J Ryan
River Basin District: ERBD	Grid ref: 688835, 769454
River Water Body: 07_1777_57	Name of Structure: Blackcastle Demesne Weir 1
Owner:	IFI Analyst: R Donovan, A O'Connell

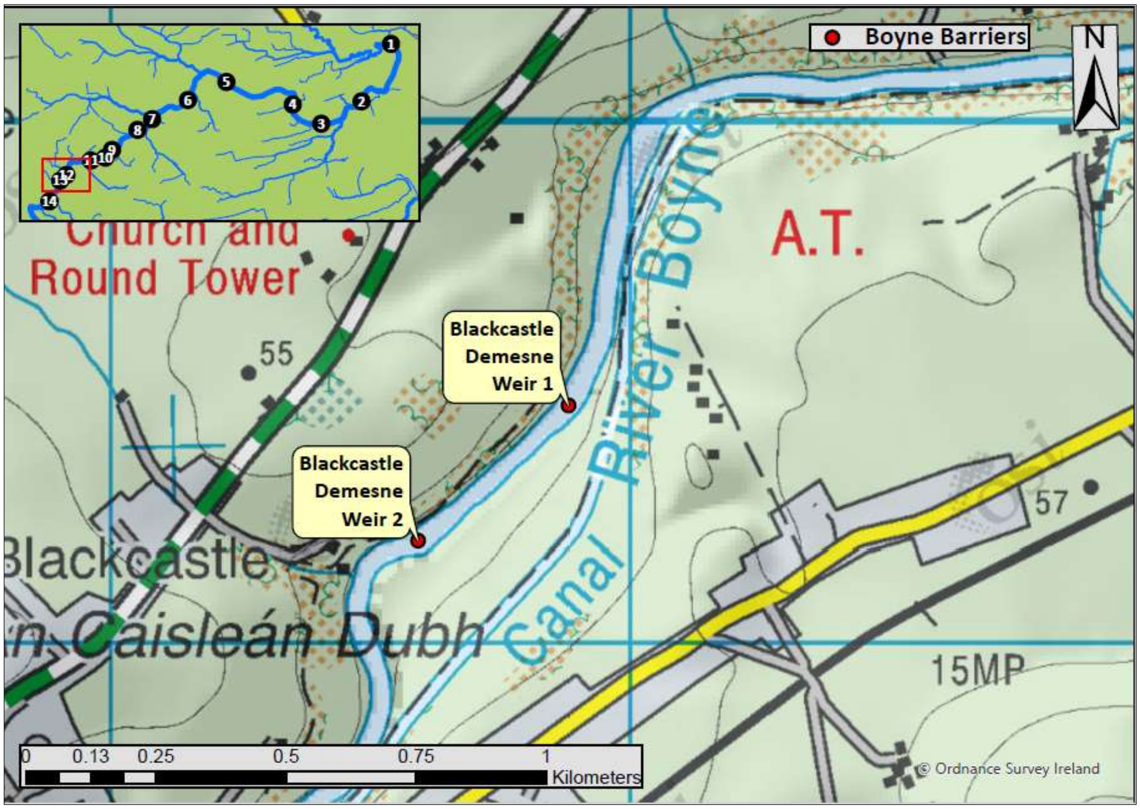


Figure 69. The location of Blackcastle Demesne Weir 1, Co. Meath

Blackcastle Demesne Weir 1 is located on the main stem of the River Boyne, Co. Meath (Figure 69). It is situated 1.52 km upstream of Dunmoe Weir and is approximately 22.5 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Blackcastle Demesne (north bank) and Ballymacon (south bank). The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. The historic 6" map depicts an area liable to flooding, a canal, and embankments in sequential order on the south bank of the weir (Figure 70). The later historic 25" map continues to denote these elements, with the exception of the embankments. Currently, the south bank of the weir is occupied by a wastewater treatment plant. Domestic wastewater is an acknowledged pressure on this section of river (EPA, 2023). The retention of water and sediment behind the weir has the potential to exacerbate the negative impacts of such a pressure. The area surrounding Blackcastle Demesne Weir 1 has a high probability of fluvial flooding with an AEP of 10% (OPW, 2019). The weir is located in the centre of the

Catchment Flood Risk Assessment and Management (CFRAM) map for Navan Tile 16 (Figure 71). These maps were produced for communities at potentially significant risk from flooding. The area surrounding the weir, particularly upstream, experienced surface water flooding during the winter of 2015/2016 (OPW, 2019).

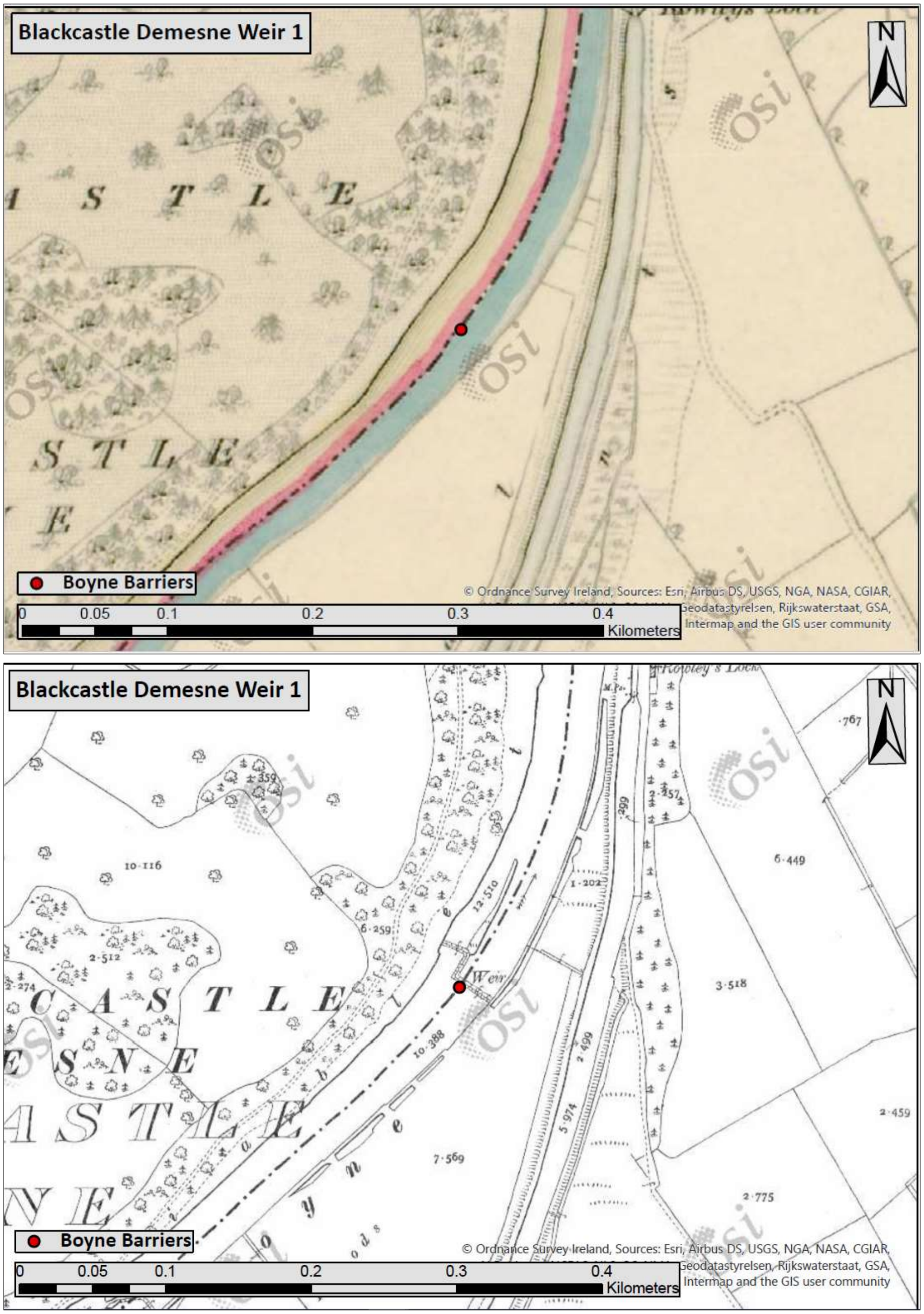


Figure 70. Location of Blackcastle Demesne Weir 1 as shown on the historic 6" OSi map, 1829-1841, (top) and on the historic 25" OSi map, 1897-1913, (bottom).

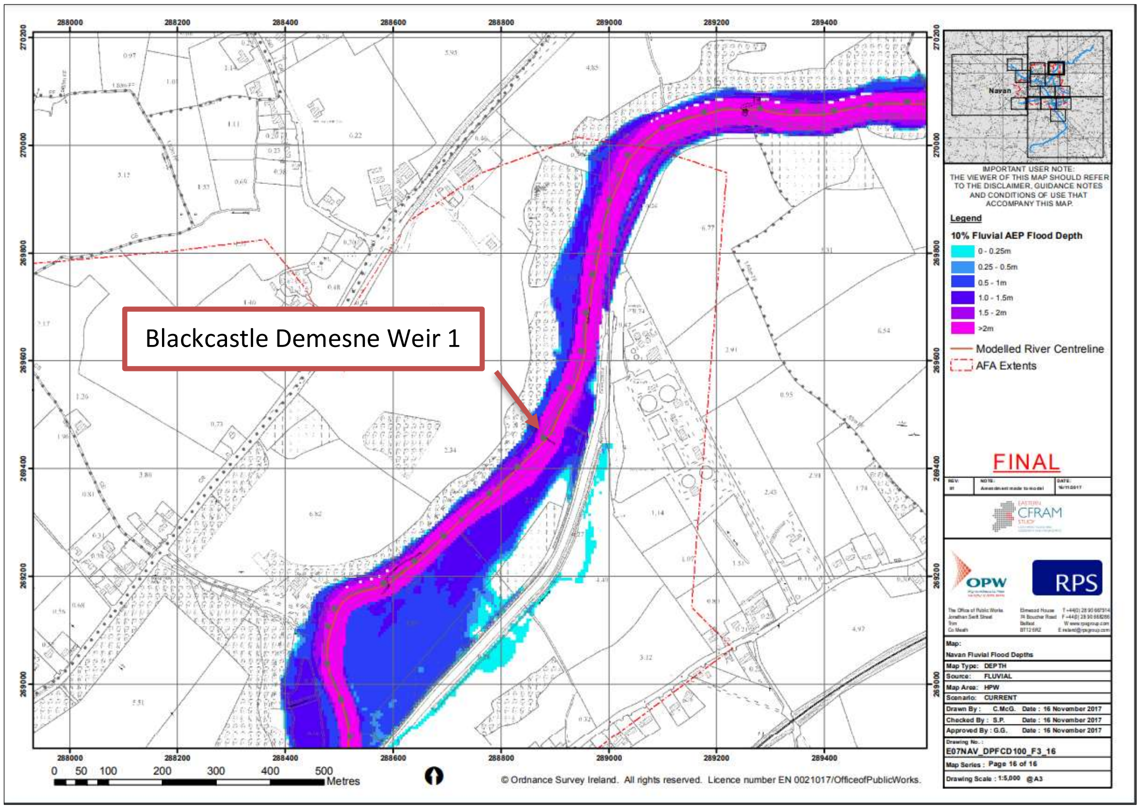


Figure 71. A Catchment Flood Risk Assessment and Management (CFRAM) Programme map of Navan Tile 16, displaying the flood depths for high probability fluvial flooding. Additional guidance notes for this map are available here: https://www.floodinfo.ie/map/general_map_user_guidance_notes/.

On the date of survey, the mean water height at Navan Weir gauging station (07009) was 0.717 m. The hydraulic head height of the weir was 0.210 m. The total width of the barrier along the crest was 65 metres, of which 41 metres were wetted. The width of the channel at this point was 48 metres. This sloping weir presented one transversal section for fish to attempt passage (Figure 72), which is described below.

Figure 72. The single transversal section of Blackcastle Demesne Weir 1. Drone imagery taken 22/09/2020.

Transversal 1:

Figure 73. Transversal Section 1.

In prevailing conditions, this transversal represented no barrier (score 1.0) to adult salmonids and juvenile eel. Cyprinids and adult lamprey encountered a high impact partial barrier (score 0.3) as a result of the outlet velocities at 60% water depth (1.69 to 2.08m/s) and at the streambed (1.2 to

1.62m/s) respectively (Figure 73). Outlet velocities and the 22.11% slope were limiting factors for juvenile salmonids, creating a low impact partial barrier (score 0.6). Juvenile eel were able to bypass the structure via a climbing substrate. Downstream migrants were unhindered (score 1.0). Higher flows would be likely to improve passage for those species encountering restrictions under the prevailing survey conditions.

Passability Assessment for Site (Table 12)

On the day of survey, Blackcastle Demesne Weir 1 facilitated the upstream passage of all species, to varying degrees. Cyprinids and adult lamprey were the species least catered for. Velocities at the outlet severely restricted their upstream migration (score 0.3). The swimming capabilities of salmonids meant they were less inhibited by this factor. Adult salmonids encountered no barrier (score 1.0), while their juvenile counterparts engaged with a low impact partial barrier (score 0.6). Juvenile eel could circumnavigate the problematic velocities via a climbing substrate. Downstream migrants were unobstructed by the weir. Higher flows would be likely to improve passage for the species hampered under the survey flow conditions.

Table 12: Final Passability Assessment for Blackcastle Demesne Weir 1.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon	current conditions	X				X			
(AS)	high flows	X				X			
Adult Trout	current conditions	X				X			
(AT)	high flows	X				X			
Cyprinids	current conditions			X		X			
(C)	high flows		X			X			
Adult Lamprey	current conditions			X					
(AL)	high flows		X						
Juvenile Eel	current conditions	X							
(JE)	high flows	X							
Juvenile	current conditions		X			X			
Salmonids (JS)	high flows	X				X			
Juvenile	current conditions					X			
Lamprey (JL)	high flows					X			
Adult Eel	current conditions					X			
(AE)	high flows					X			

13. Blackcastle Demesne Weir 2

River: Boyne	Survey Date: 22/09/2020
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, R O'Briain, J Ryan
River Basin District: ERBD	Grid ref: 688527, 769180
River Water Body: 07_1777_25	Name of Structure: Blackcastle Demesne Weir 2
Owner:	IFI Analyst: R Donovan, A O'Connell

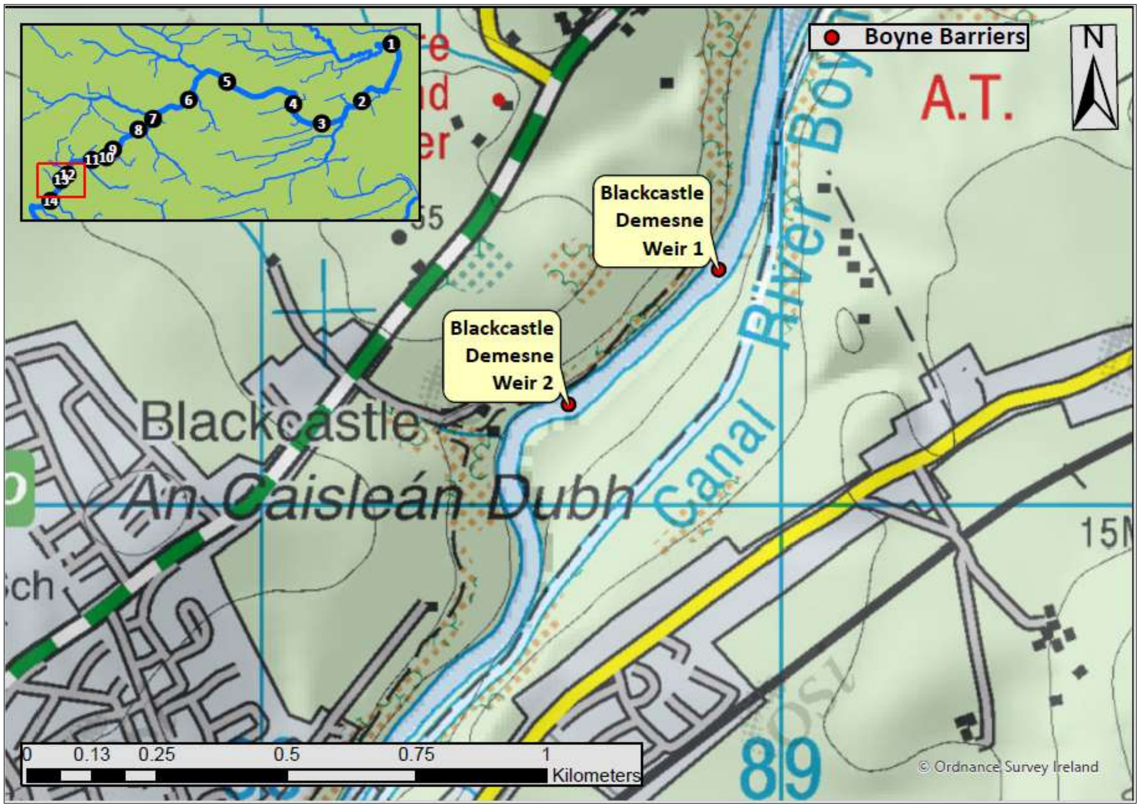


Figure 74. The location of Blackcastle Demesne Weir 2, Co. Meath.

Blackcastle Demesne Weir 2 is located on the main stem of the River Boyne, Co. Meath (Figure 74). It is situated 0.41 km upstream of Blackcastle Demesne Weir 1 and is approximately 23 km from the tidal limit at Oldbridge Weir. The structure rests on the border between the townlands of Blackcastle Demesne (north bank) and Ballymacon (south bank). The weir impacts upon a section of river that forms part of the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is situated in a stretch of river with "Moderate" ecological status. The historic 6" map depicts a "Fish Weir" in the current location of Blackcastle Demesne Weir 2 (Figure 75). Between the river and the canal on the south bank, there is an area recorded as "The Boyne Meadow". The later historic 25" map depicts this same area as "Liable to Floods". The current form of the weir is outlined by the 25" map, but the structure retains the "Fish Weir" label. A salmon hatchery is illustrated upstream of the structure, on the north bank. The area surrounding Blackcastle Demesne Weir 2 has a high probability of fluvial flooding with an AEP of 10% (OPW, 2019). The weir is located at the southern end of the Catchment Flood Risk Assessment and Management (CFRAM) map for Navan Tile 16 (Figure 71). These maps were produced for communities at potentially significant risk from flooding. The area surrounding the weir, particularly the south bank, experienced surface water flooding during the winter of 2015/2016 (OPW, 2019).

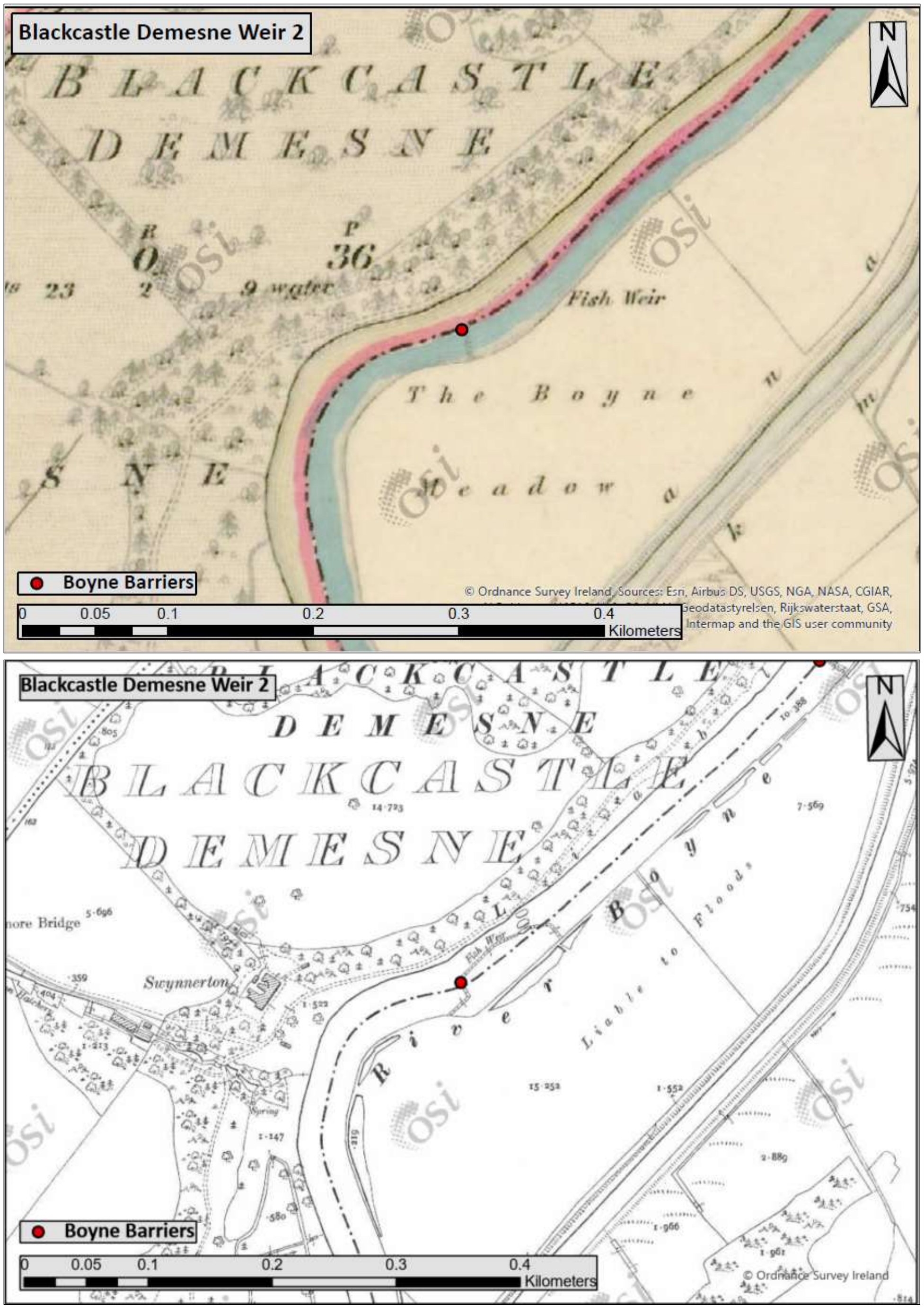


Figure 75. Location of Blackcastle Demesne Weir 2 as shown on the Historic 6" First Edition OSi map, 1829-1841, (top) and on the Historic 25" OSi map, 1897-1913, (bottom).

On the date of survey, the mean water height at Navan Weir gauging station (07009) was 0.717 m. The hydraulic head height of the weir was 0.275 m. The total width of the barrier along the crest was 112 metres, of which 90 metres were wetted. The width of the channel at this point was 50 metres.

This sloping weir presented three transversal sections for fish to attempt passage (Figure 76), which are described below.

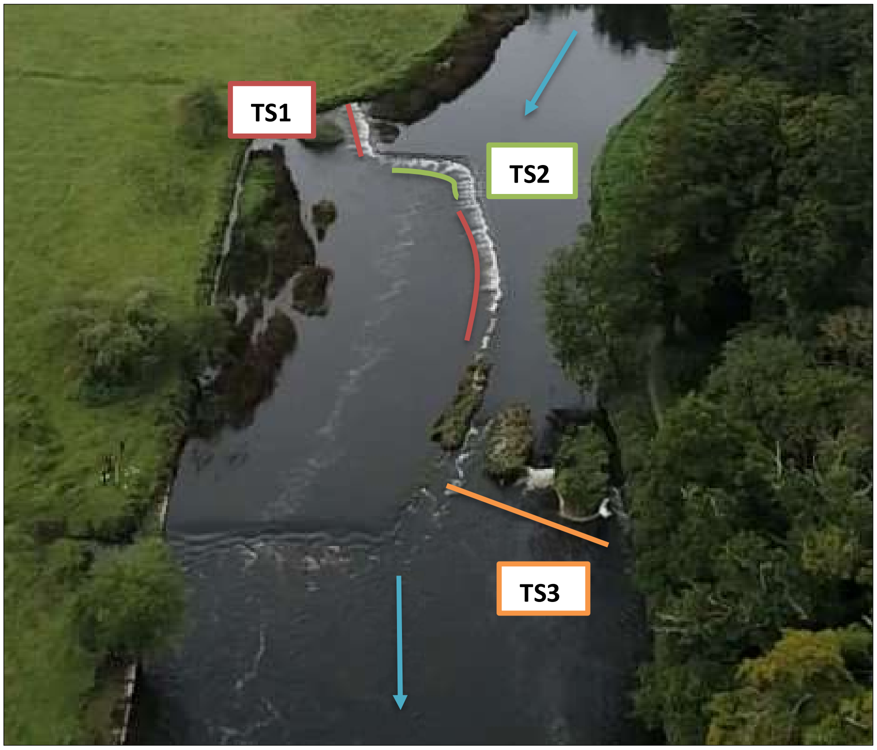


Figure 76. The three transversal sections of Blackcastle Demesne Weir 2. Drone imagery taken 22/09/2020.

Transversal 1:

Figure 77. Transversal Section 1.

In prevailing conditions, this transversal represented high impact partial barrier (score 0.3) for all upstream migrating species, with the exception of juvenile eel. The primary obstacle to passage was the presence of a standing wave (Figure 77). A compounding limiting factor for cyprinids and adult lamprey was created by the midpoint and outlet velocities at 60% depth (1.75 to 2.33m/s) and the streambed (1.17 to 2.09 m/s) respectively. Juvenile eel were able to bypass the structure via a climbing substrate and thus encountered no barrier (score 1.0). Downstream migrants were unhindered (score 1.0). Higher flows would be likely to improve passage for all species.

Transversal 2:

Figure 78. Transversal Section 2.

In prevailing conditions, this transversal represented high impact partial barrier (score 0.3) for all upstream migrating species, with the exception of juvenile eel. The primary obstacle impacting all upstream migrants was the presence of a standing wave (Figure 78). Additional challenges, that were particularly limiting for species other than adult salmonids, included midpoint velocities and medium levels of turbulence. Without an available climbing substrate, juvenile eel were fully exposed to water flow and encountered a complete barrier (score 0.0). Downstream migrants were unhindered (score 1.0). Higher flows would be likely to improve passage for all species except juvenile eel.

Transversal 3:

Figure 79. Transversal Section 3.

In prevailing conditions, this transversal represented high impact partial barrier (score 0.3) for all upstream migrating species, with the exception of juvenile eel. The primary obstacle impacting upstream migrants was the presence of a standing wave (Figure 79). Additional challenges, that were particularly limiting for species other than adult salmonids, included outlet and inlet velocities, medium levels of turbulence, and the effective length (6.2 m). Due to the presence of a climbing substrate, juvenile eel could bypass the water flow and encountered no barrier (score 1.0). Downstream migrants were unhindered (score 1.0). Higher flows would be likely to improve passage for all species.

Passability Assessment for Site (Table 13)

On the day of survey, Blackcastle Demesne Weir 2 facilitated the upstream passage of all species. The structure was predominantly a high impact partial barrier (score 0.3). However, juvenile eel were able to circumnavigate the structure via climbing substrates at transversals 1 and 3. They thus encountered no barrier (score 1.0). The three transversals all posed similar disturbances to upstream movement. Water velocity and the presence of standing waves were common limiting factors. Downstream migrants were unobstructed by the weir and had their choice of routes. Higher flows would be likely to improve passage for all species.

Table 13: Final Passability Assessment for Blackcastle Demesne Weir 2.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions			✘		✘			
	high flows	✘				✘			
Adult Trout (AT)	current conditions			✘		✘			
	high flows	✘				✘			
Cyprinids (C)	current conditions			✘		✘			
	high flows		✘			✘			
Adult Lamprey (AL)	current conditions			✘					
	high flows		✘						
Juvenile Eel (JE)	current conditions	✘							
	high flows	✘							
Juvenile Salmonids (JS)	current conditions			✘		✘			
	high flows		✘			✘			
Juvenile Lamprey (JL)	current conditions					✘			
	high flows					✘			
Adult Eel (AE)	current conditions					✘			
	high flows					✘			

14. Blackcastle Weir

River: Boyne	Survey Date: 24/01/2019
Tributary: N/A, main channel	IFI Surveyors: B Coghlan, J Barry, C Fleming
River Basin District: ERBD	Grid ref: 688021 768251
River Water Body: 07_1538_59	Name of Structure: Blackcastle Weir
Owner: Boyne Navigation	IFI Analyst: R Donovan

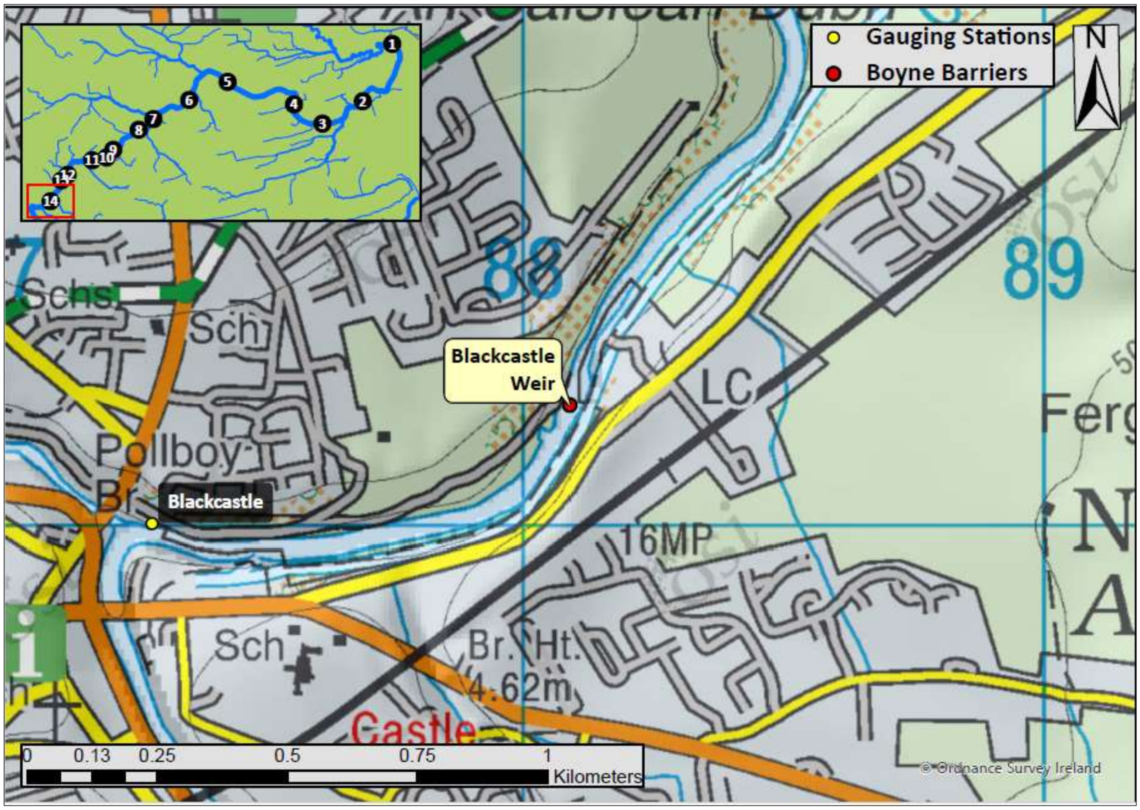


Figure 80. The location of Blackcastle Weir in Navan, Co. Meath.

Blackcastle Weir is located on the main stem of the River Boyne, to the east of Navan, Co. Meath (Figure 80). It is on the border between the townlands of Athlumney and Blackcastle Demesne. The structure is located 1.57 km upstream of Blackcastle Demesne Weir 2 and approximately 24.5 km upstream of the tidal limit at Oldbridge Weir. The weir is within the River Boyne and River Blackwater SAC and SPA. According to the WFD River Waterbody Status (2013-2018), the weir is located in an area of "Moderate" quality, downstream of where a "Poor" segment of the Kells Blackwater merges with a "Good" stretch of the Boyne. A weir is visible on the historic 6" First Edition OSi maps (1829-1841), suggesting that a structure has existed in this location since at least the early 19th century (Figure 81).

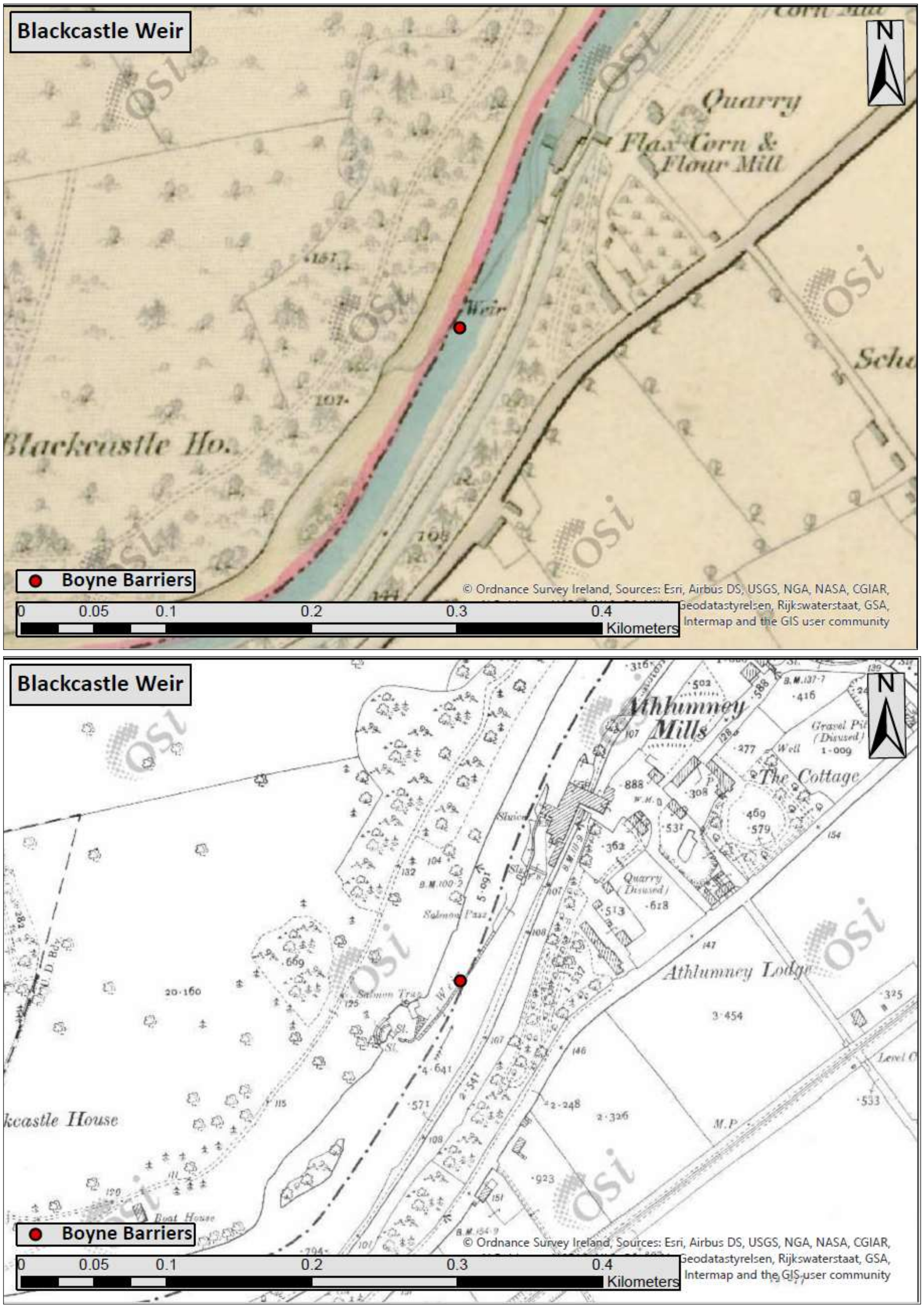


Figure 81. Top: Location of Blackcastle Weir, bordered by Blackcastle House on the left bank and a flax, corn, and flour mill on the right bank as shown on the Historic 6" First Edition OSi map (1829-1841). Bottom: The weir as depicted on the Historic 25" OSi map (1897-1913) with Athlumney Mills and a disused quarry on the right bank.

On the date of survey, flow conditions were elevated to a water height of 0.501 m. The width of the barrier along the crest was 142 metres, of which 130 metres were wetted. The width of the channel at this point was 47 metres. The weir presented vertical, crump, and stepped facets, in addition to a sluice. Six transversal sections were available for fish to attempt passage. There were six fish counters present on the structure, comprised of two Vaki and four Logie (Figure 82).

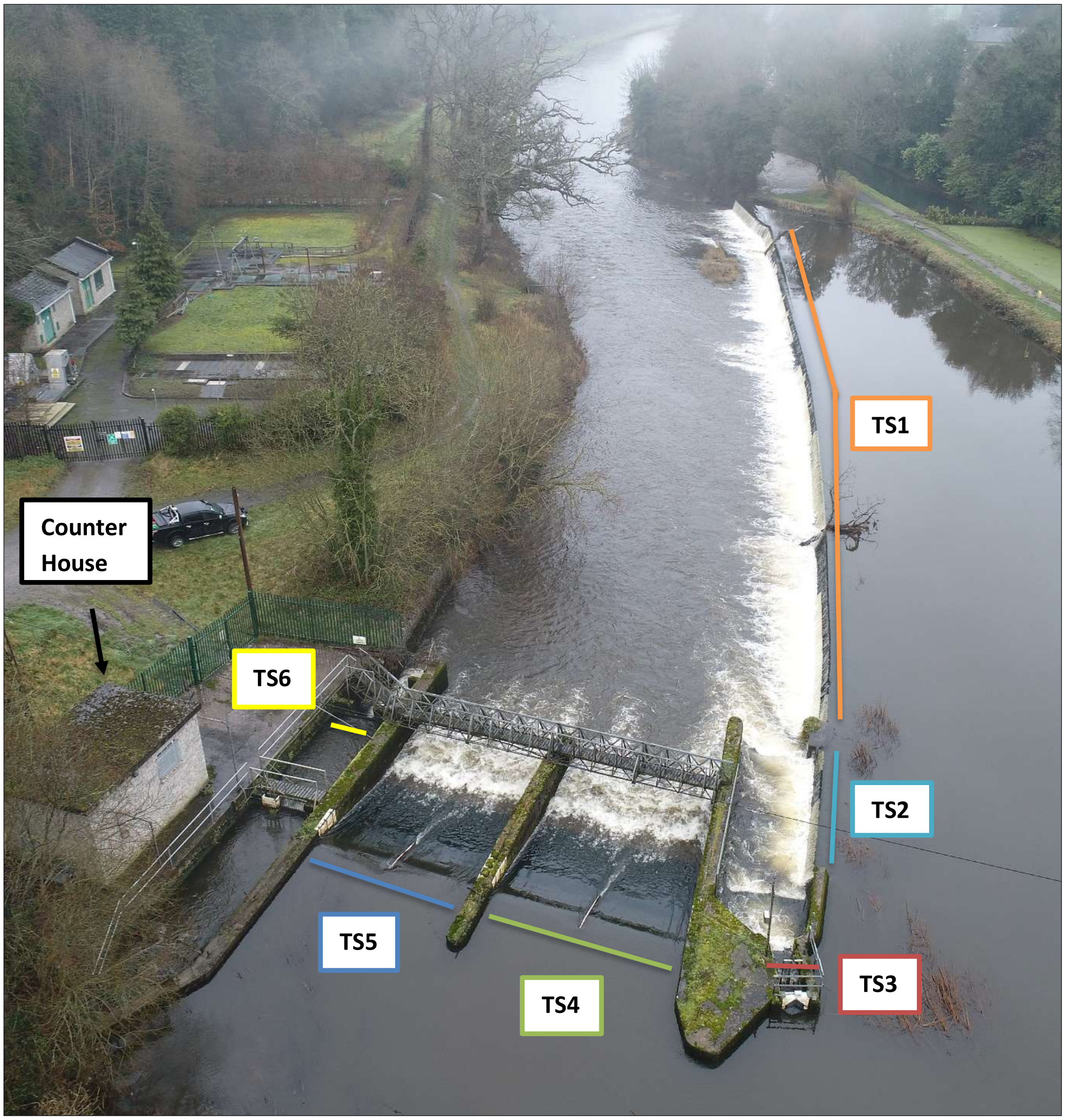


Figure 82. Blackcastle weir with transversal sections (TS) marked.

Transversal 1:

In prevailing conditions, this vertical weir face was a complete barrier (score 0.0) to the upstream migration of all species except adult salmon. The hydraulic head height (1.1 m) was the primary obstacle (Figure 83). At over a metre, it was a complete jump barrier for adult trout, cyprinids, adult lamprey, and juvenile salmonids. However, for adult salmon, the head height represented a surmountable high impact partial barrier (score 0.3). The inlet velocities at the streambed (0.97 to

1.16 m/s) were a compounding obstacle for juvenile eel. As no alternative climbing substrate was available, the velocities created an unavoidable complete swim barrier for the species. Downstream migrants, including juvenile lamprey and adult eel, faced no barrier (score 1.0) at this fish passage option. Higher flows would be likely to increase passability for all species except juvenile eel.

Figure 83. Transversal Section 1- vertical weir face.

Transversal 2:

Figure 84. Transversal Section 2- vertical drop.

In prevailing conditions, this vertical drop was a complete barrier to the upstream migration of all species except adult salmonids. The hydraulic head height (0.55 m) was a complete jump barrier for cyprinids, adult lamprey, and juvenile salmonids (Figure 84). The head height also impacted adult trout, although to a lesser extent, creating a low impact partial barrier (score 0.6). The medium levels of turbulence were an additional low impact partial barrier (score 0.6) for adult trout. While the hydraulic head height represented no barrier (score 1.0) to adult salmon, the medium turbulence constituted a low impact partial barrier (score 0.6) for the species, similar to adult trout. As no alternative climbing substrate was available, the transversal was a complete barrier (score 0.0) to juvenile eel. Downstream migrants faced no barrier (score 1.0) at this transversal. Higher flows are unlikely to improve passage for adult salmonids, as a decrease in turbulence levels is improbable. Similarly, juvenile eel would likely continue to struggle without a viable climbing substrate. However, the remaining species may benefit from increased flows.

Transversal 3:

Figure 85. Transversal Section 3- three steps into Vaki trap.

In prevailing conditions, this stepped section leading into a fish counter represented a complete barrier (score 0.0) for the upstream migration of all species except adult salmonids (Figure 85). The final step height (0.4 m) was a complete jump barrier for cyprinids, adult lamprey, and juvenile salmonids. The primary obstacle for adult salmon and adult trout were the medium levels of turbulence, which created a low impact partial barrier (score 0.6). Turbulence was a significant barrier for other upstream migrants also but was superseded by the final step height as the main barrier. A climbing substrate was available, however, it would likely by inaccessible to juvenile eel. Downstream migrants faced no barrier (score 1.0) traversing this route. Higher flow would have the potential to improve passage for cyprinids, adult lamprey, and juvenile salmonids. However, increased turbulence and velocities may negate the benefit of an increase in water volume. Adult salmonid passage is unlikely to improve in the event of higher flows due to an improbable reduction in turbulence.

Transversal 4:

Figure 86. Transversal Section 4-crump, Logie counter.

This crump section of the weir had a Logie fish counter. In prevailing conditions, the route was a complete barrier (score 0.0) for all species travelling upstream. The velocities, especially at the midpoint and the outlet created a major swim obstacle (Figure 86). A compounding complete barrier (score 0.0) for cyprinids, adult lamprey, and juvenile salmonids was the slope (19.81%). Downstream migrants encountered no barrier at this transversal. Higher flows would be unlikely to improve passage for species attempting to traverse this section of Blackcastle Weir.

Transversal 5:

Figure 87. Transversal Section 5-crump, Logie counter.

This potential passage route was very similar to transversal 4. Once again, this crump section of the weir had a Logie fish counter present. In prevailing conditions, the structure was a complete barrier (score 0.0) to all species attempting to migrate upstream. Velocity was the primary issue, particularly at the midpoint and outlet (Figure 87). A compounding complete barrier (score 0.0) for cyprinids, adult lamprey, and juvenile salmonids was the slope (19.81%). The transversal posed no barrier (score 1.0) to downstream migrants. Higher flows would be unlikely to improve passage for species attempting to traverse this transversal.

Transversal 6:

Figure 88. Transversal Section 6-sluice.

This undershot sluice had a gate that was almost completely closed on the date of survey. A notch and two boxes were also present. In prevailing conditions, the sluice was a complete barrier to all species migrating upstream except adult salmonids (Figure 88). The high levels of turbulence were a complete swim barrier (score 0.0) for cyprinids, adult lamprey, juvenile eel, and juvenile salmonids. Adult salmonids were also impacted by the turbulence, although to a lesser degree. They faced a high impact partial barrier (score 0.3). High velocities at the inlet were a compounding complete barrier for non-salmonids. Downstream migrants encountered no barrier (score 1.0) at this transversal. Higher flows would be unlikely to alter the passability scores for any species.

Final Passability Assessment for Site (Table 14)

On the date of survey, Blackcastle Weir represented a complete barrier (score 0.0) to the upstream migration of all species except adult salmonids (Table 14). Both adult salmon and adult trout could make passage at transversals 2,3, and 6. Adult salmon could also surmount the weir at transversal 1, although it represented a high impact partial barrier (score 0.3). The remaining species migrating upstream had no viable route to traverse the weir. Downstream migrants could utilise any of the 6 transversals to descend the structure. In higher flows, transversals 1, 2, and 3 could potentially open up as passage routes for cyprinids, adult lamprey, and juvenile salmonids. Regardless of flow, transversal 3 provided the best passage option available overall.

Table 14: Final Passability Assessment for Blackcastle Weir.

		UPSTREAM MIGRATION				DOWSTREAM MIGRATION			
		No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0	No barrier 1	Partial barrier Low impact 0.6	Partial barrier High impact 0.3	Complete barrier 0.0
Adult Salmon (AS)	current conditions		X			X			
	high flows		X			X			
Adult Trout (AT)	current conditions		X			X			
	high flows		X			X			
Cyprinids (C)	current conditions				X	X			
	high flows			X		X			
Adult Lamprey (AL)	current conditions				X				
	high flows			X					
Juvenile Eel (JE)	current conditions				X				
	high flows				X				
Juvenile Salmonids (JS)	current conditions				X	X			
	high flows			X		X			
Juvenile Lamprey (JL)	current conditions					X			
	high flows					X			
Adult Eel (AE)	current conditions					X			
	high flows					X			

Mitigation Options

Artificial barriers impair the migration of fish and other stream biota to and from the habitats they require to spawn, feed, and seek refuge. Without access to these habitats, they cannot complete their life cycle and sustain their populations. Species must be free to travel to a variety of habitats that fulfil different requirements. For example, Atlantic salmon parr travel both upstream and downstream to access better feeding grounds than those offered by their natal streams, or to find refuge from low water levels and temperature changes (McCormick *et al.*, 1998). Amelioration of artificial barriers can be achieved to varying degrees by removal, breaching, or installation of a fish passage structure. Below, potential mitigation options and their pros and cons are provided.

Barrier removal: Barrier removal is the preferred option from a continuity perspective because it is most effective at reconnecting isolated habitat patches. This approach facilitates the longitudinal passage of biota, but also improves water and sediment movement, which is critical to habitat forming processes. However, removal is not always undertaken due to issues related to the current use or ownership of the structure. As an alternative, existing structures may be modified or new functioning structures installed in order to achieve partial connectivity.

Barrier breaching: Barrier breaching is the next best option. Similar results to barrier removal are achieved, while retaining some part of the original weir structure (Figure 89). It solves all upstream and downstream fish passage issues, is cheaper than a built fish passage option, addresses other problems such as structural safety, and does not hinder future options. However, as with barrier removal, there may be some societal and cultural issues. For example, some weirs have historical value or form part of the social heritage of an area.

Figure 89. Photos of breached weirs: (A) Ballyclough Weir in the Mulkear River, Co. Limerick, and (B) Kent Dam in the Cuyahoga River, Ohio, USA (breach in far right of image).

Fish passage structure: River infrastructure provides services that may be deemed too expensive or impractical to remove. Sometimes there can also be opposition to the proposed decommissioning projects. Retrofitting of barriers with fish passage structures (i.e. bypass channels or fishways) is therefore an option where removal is not feasible. There are two components to effective fish passage:

> **Attraction** - which involves designing fish passage options to ensure that the hydraulic conditions (flow paths and turbulence) near the structure guide fish to the fishway entrance or entrances.
>
> **Passage** - which involves the hydraulic and structural design of the fishway itself.

Fish passage must be constructed to accommodate the range of needs and swimming abilities of the many species of concern. After this consideration, basic approaches and principles can be identified for the design of fish passage facilities in all river systems. These are:

1. The smallest migrants usually have the weakest swimming ability, and this determines the maximum water velocity, turbulence, and gradient of upstream fishways.
2. The largest migrants and the volume of migratory biomass desired will determine the size, depth, space, and flow required in the fishway.
3. Headwater and tailwater levels determine the depths, operating range, length, and gradient of fishways.
4. Fishway entrances and designs may be substantially different for fish migrating at high flows during the wet seasons and fish migrating at low flows during the dry season.
5. For fish that only migrate during the daylight hours or the night-time hours, the fishway may need to incorporate large resting pools.
6. To meet fish passage objectives, upstream passage needs to consider adult fish (of varying sizes) and juvenile eel, while downstream passage needs to consider adult fish returning to sea, eggs, larvae, and juveniles.

Well-designed bypass channels can afford passage both upstream and downstream for fish and other stream biota (Figure 90). These will attempt to replicate conditions in natural channels by providing appropriate flow conditions, substrate type, plant cover and resting areas for fish. Bypass channels may also, to some extent, accommodate more natural flow and sediment movement downstream.

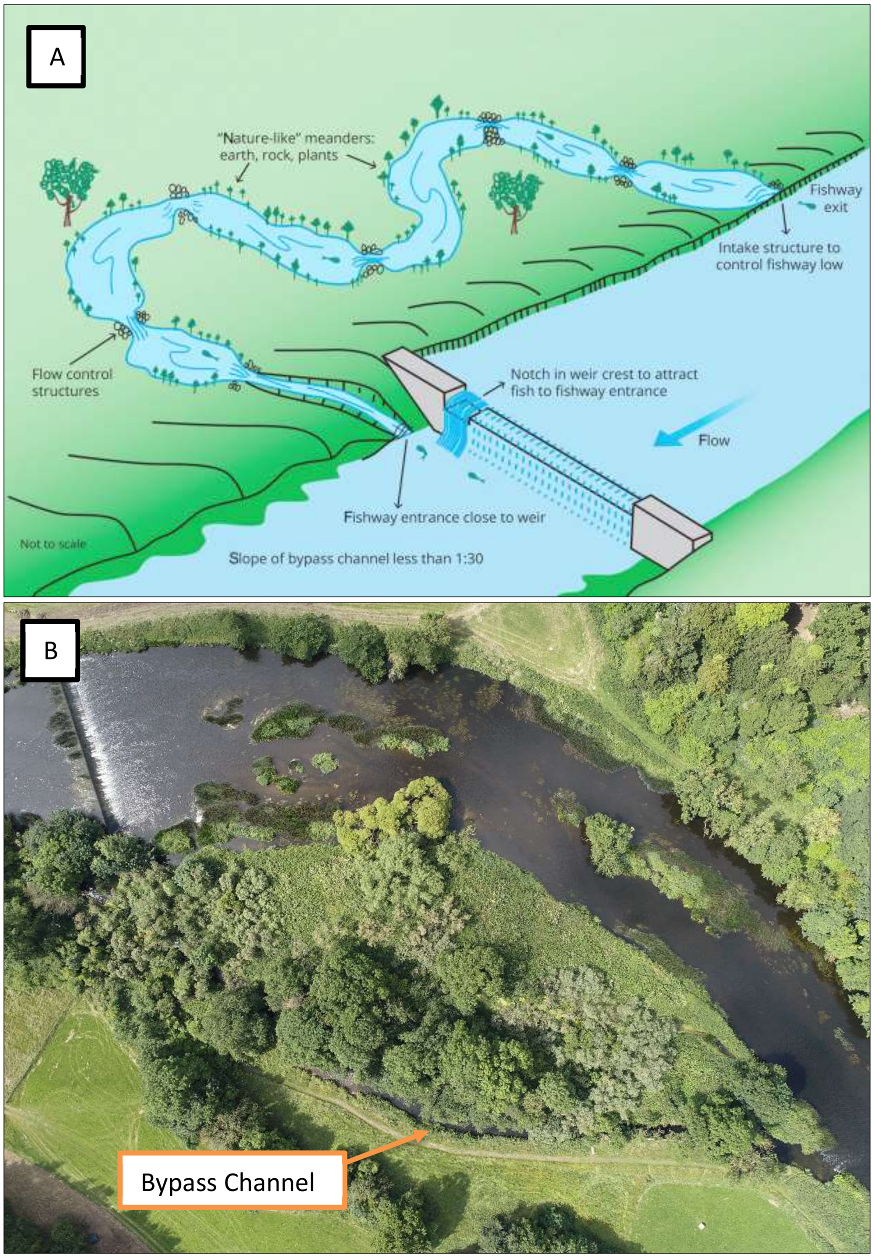


Figure 90. A) Illustration of a bypass channel for promoting the passage of fish and other stream biota (Thomas, 2017). B) Bypass channel on the River Boyne mitigating a weir by Slane Castle. Drone imagery taken 13/07/2021.

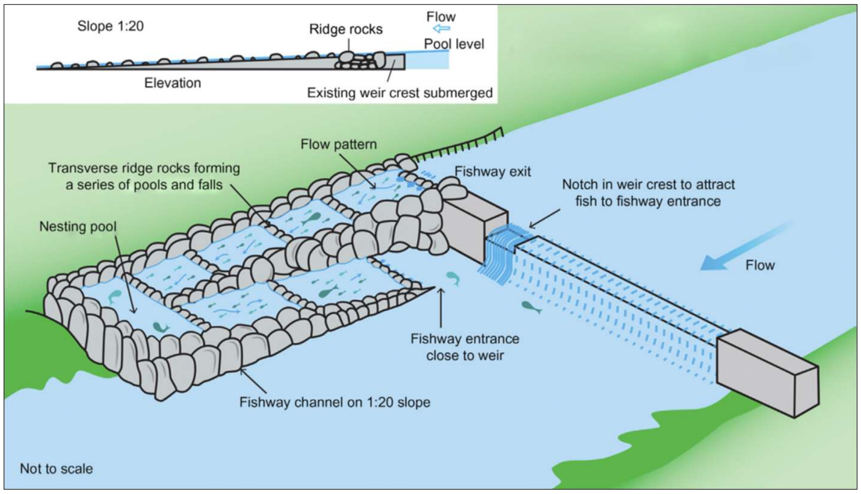


Figure 91. Illustration of partial-width pool and boulder rock-ramp fishway (Thomas, 2017).

A final mitigation option is the provision of a fishway (Figure 91 and 92). This is the most limited option in terms of connectivity, but it will at least provide for fish passage, if designed correctly. Fishways are low-gradient, stair-like structures featuring a series of steps interspersed with resting areas. They are designed to dissipate flow velocity and turbulence, thereby allowing fish to swim up and over barriers. Globally, fishways have proven most effective at facilitating the passage of large-bodied salmonids, but are often ineffective for smaller-bodied, slower swimming species (Mallen-Cooper & Brand, 2000; Katopodis & Aadland, 2006). As such, due care must be taken during design to achieve effective fish passage for all species of concern.

Figure 92. A full width pool and boulder rock ramp type fishway at Tuckmill Bridge, River Slaney, designed to mitigate the barrier impact of a bridge apron/culvert.

The pool and boulder rock ramp fishway is considered to be among the most effective form of fish pass (Figures 92). Its gentle gradient, availability of resting places within the pools and appropriately sized gaps between the transverse rock ridges can accommodate a large variety of fish species.

Improving Connectivity in the River Boyne

The main stem of the River Boyne from Navan to Drogheda is affected by artificial structures and by physical habitat modifications throughout, resulting in poor ecological and hydrological connectivity. The sequence of 14 barriers presents a challenge for species movement, which becomes cumulatively harder as biota move through the system. The cumulative impact of multiple structures is demonstrated by Table 16. The percentage of Atlantic salmon moving upstream declines with each barrier encountered. Although a higher percentage would successfully migrate upstream under higher flow conditions, the figure continues to dwindle with each additional structure. Species such as lamprey, which exhibit limited swimming capabilities when compared to salmon, are barricaded downstream to an even greater extent (Table 15).

Table 15. The barrier scores for the upstream migration of individual species at each structure assessed. Red indicates a complete barrier (0), orange indicates a high impact partial barrier (0.3), light green indicates a low impact partial barrier (0.6), and dark green represents no barrier (1).

Barriers moving upstream in order from Drogheda towards Navan		Barrier Score for Upstream Migration in Survey Conditions					
		Adult Salmon	Adult Trout	Cyprinids	Adult Lamprey	Juvenile Eel	Juvenile salmonids
1	**Oldbridge Weir**	0.6	0.6	0.3	0.3	1	0.3
2	**Dowth Weir**	1	1	0.3	0.6	1	0.6
3	**Roughgrange Weir**	0.6	0.6	0.3	0.3	0.3	0.3
4	**Newgrange Weir**	0.3	0.3	0.3	0.3	1	0.3
5	**Slane Weir**	0.6	0.3	0.3	0.3	1	0.3
6	**Carrickdexter Weir**	0.3	0.3	0	0.3	0	0.3
7	**Dollardstown Weir**	0.3	0.3	0	0	1	0
8	**Stackallan Weir**	0	0	0	0	1	0
9	**Ardmulchan Weir 1**	1	1	0.6	0.6	1	0.6
10	**Ardmulchan Weir 2**	0.6	0.6	0.3	0.3	1	0.3
11	**Dunmoe Weir**	0.3	0.3	0	0.3	1	0.3
12	**Blackcastle Demense Weir 1**	1	1	0.3	0.3	1	0.6
13	**Blackcastle Demense Weir 2**	0.3	0.3	0.3	0.3	1	0.3
14	**Blackcastle Weir**	0.6	0.6	0	0	0	0

Slane is regularly considered a cut off point for anadromous species during the summer months. From July, Grilse fishing is primarily confined to the section of the Boyne located between Slane and Drogheda (O' Reilly, 2002). Occurring from May to September, the sea trout run is mostly limited to Oldbridge, but can extend to Slane Bridge (O' Reilly 2022, IFI 2023). These records correlate with the results of the SNIFFER assessments displayed in Table 16. Thirteen of the 14 structures in this report were evaluated during lower flows from July to September. After Slane Weir, only 6.48% of the original salmon population are available to continue upstream. This is equivalent to approximately 6 fish for every 100 that return during the summer season. Anglers based further upstream would benefit from increased stock if the blockading structures were to be mitigated.

Table 16. The percentage of Atlantic salmon progressing upstream after each barrier under both survey and high flow conditions. Red indicates a complete barrier (0), orange indicates a high impact partial barrier (0.3), light green indicates a low impact partial barrier (0.6), and dark green represents no barrier (1).

Barriers moving upstream in order from Drogheda towards Navan		**Survey Conditions**		**High Flows**	
		% of Atlantic salmon progressing upstream	Barrier score	% of Atlantic salmon progressing upstream	Barrier score
1	**Oldbridge Weir**	60.00	0.6	100.00	1
2	**Dowth Weir**	60.00	1	100.00	1
3	**Roughgrange Weir**	36.00	0.6	60.00	0.6
4	**Newgrange Weir**	10.80	0.3	18.00	0.3
5	**Slane Weir**	6.48	0.6	18.00	1
6	**Carrickdexter Weir**	1.94	0.3	10.80	0.6
7	**Dollardstown Weir**	0.58	0.3	6.48	0.6
8	**Stackallan Weir**	0.00	0	3.89	0.6
9	**Ardmulchan Weir 1**	0.00	1	3.89	1
10	**Ardmulchan Weir 2**	0.00	0.6	2.33	0.6
11	**Dunmoe Weir**	0.00	0.3	1.40	0.6
12	**Blackcastle Demense Weir 1**	0.00	1	1.40	1
13	**Blackcastle Demense Weir 2**	0.00	0.3	1.40	1
14	**Blackcastle Weir**	0.00	0.6	0.84	0.6

The remediation of barriers would also benefit the species themselves. Were all 14 structures to be improved, large stretches of river with “Good” or “Moderate” WFD status would be opened within the main channel and tributaries of the Boyne (Figure 93). A longitudinally free-flowing stretch of 132.70 km would be created. This newly accessible downstream reach of the lower Boyne would be particularly valuable to anadromous species. Fish could move upstream from their estuarine access point into the Boyne system with ease.

Shad, a species not considered in the SNIFFER assessment, has been reported in the Boyne Estuary. As an anadromous species, access to the upper reaches of the Boyne would be essential for life cycle completion. The removal of barriers and impoundments would result in more favourable conditions for shad. Greater mitigation measures would be necessary to facilitate passage for shad than for adult salmonids. The species does not jump and has a lesser swimming ability. Furthermore, shad have a lower tolerance for higher water velocities and trouble orientating in turbulent flows. Traditionally, fish passes have had a low success rate for shad (Larinier and Travade, 2002). Barrier removal or breaching would be the most appropriate options to enable the species’ access to the Boyne.

Culturally, mitigation of the 14 structures is important. The loss of salmon to the Boyne would be particularly profound considering the river’s heritage. The removal of obstacles would support the continued existence of a salmon population that has been relevant to our culture for over a thousand years. It would also provide an opportunity to rehabilitate drowned heritage sites, such as Lugaree upstream of Stackallan Weir.

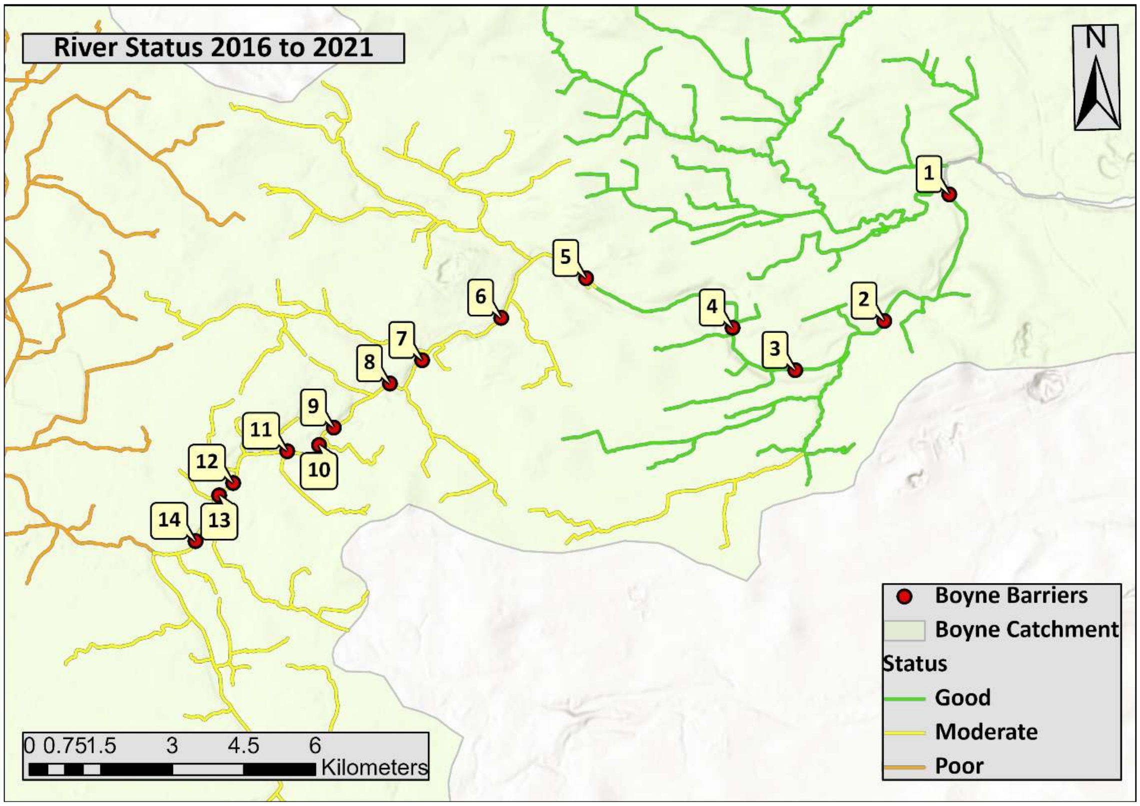


Figure 93. The 2016 to 2021 River Waterbody WFD Status of the main channel of the River Boyne and its tributaries.

The alleviation of barriers would aid Ireland in meeting its legal obligations under European Directives. Fish communities are an important factor when calculating the WFD status of a waterbody. Improving connectivity and fish stocks would contribute to achieving and maintaining the required "Good" status of waterbodies required by the Water Framework Directive. Failure to fulfil our obligations under E.U. Directives can result in fines. In January 2023, the European Commission referred Ireland to the EU Court of Justice for being in breach of the WFD and failing "to provide for appropriate controls in the following areas: water abstraction, impoundment and activities causing hydro-morphological changes such as dams, weirs and other interferences in natural water flow" (European Commission, 2023). The EU Court of Justice can impose fines of multiple millions, with additional penalties accumulating for each day that the issues remain unresolved. Furthermore, the remediation works would contribute to objectives outlined by The EU Biodiversity Strategy 2030, such as opening 25,000 km of rivers in Europe.

A well-connected river habitat is more resistant and resilient to negative events and pressures because it allows the natural recolonisation of upstream, downstream, and tributary environments by stream biota. It also allows natural habitat forming processes, like downstream sediment transport, to take place. The movement of substrate replenishes spawning areas and dwelling habitats for fish, invertebrate and plant species. Additionally, longitudinal connectivity supports a natural flow and temperature regime, which favours the adaptations of native species and increases the river's resilience to climate change.

The original purpose of many of these artificial structures is now mostly obsolete and they should be removed, breached, or mitigated wherever possible. Most of the structures are in various states of disrepair and are hundreds of years old, which presents a public safety issue. Without planned removal, these barriers are at risk of collapsing without warning and causing unmitigated and unforeseen damage. Removal would allow the state to control and protect against any potential consequences.

Barrier removal or breaching will require the relevant structural, hydrological, and hydromorphological surveys to assess feasibility. Bypass channels may be a viable alternative in some cases but opportunities for their construction may be limited, due to a lack of lateral space. The bypass channel already installed by Slane Castle, only a kilometre upstream of barrier 5, could serve as a prototype for future works in the area. Defunct canals, such as adjacent to Newgrange Weir, may be an opportunity for this form of mitigation. The last option is the installation of a fish pass. In this event, the preference is for the construction of a gently sloping pool and boulder rock ramp (Figure 94). Whenever it is practical, the removal of artificial barriers to create a naturally connected river habitat is preferable to installing engineered fishways. Man-made fish passage options are expensive and require long-term maintenance.

Figure 94. A full-width pool and boulder rock ramp fish pass designed to mitigate the impact of a weir on fish passage [https://catchmentsolutions.com.au/portfolio/rock-ramp-fishway/.](https://catchmentsolutions.com.au/portfolio/rock-ramp-fishway/)

Mitigation of the furthest downstream barrier first, followed by each consecutive barrier progressing in an upstream direction, would offer the most immediate benefits for fish passage. If remediation works are possible at only one structure, the removal of Stackallan Weir would unlock to some extent the upper Boyne catchment. This structure represents the greatest challenge for fish passage. However, this singular mitigation would insufficiently address passage issues for other important native fish, such as the Annex II listed river and sea lamprey species.

Conclusions

The River Boyne has a range of barrier types disrupting habitat quality and ecological connectivity. The weirs listed in this report are significantly disruptive. Measures aimed at mitigating artificial barriers, such as removal, breach, or bypass, are likely to improve ecological connectivity and benefit a range of stream biota. The Boyne still retains considerable ecological potential. The density and dispersal of migratory species such as Atlantic salmon will improve with mitigation efforts. By improving longitudinal connectivity, the habitat available to other important native species will also increase. Additional benefits to the mitigation of barriers would include improved fish stocks for angling, contributions to the achievement of legally mandated European targets, increased resilience to climate change, and the preservation of a culturally important salmon population.

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