December 2008

Assessment of the Risk of Barriers to Fish Migration in the Nore Catchment

Assessment of the risk of in-river barriers to fish migration, on a case study basis in the River Nore (Southern Regional Fisheries Board area), which can be used subsequently as a mechanism to assess the risk of river barriers to fish migration nationally.

Southern Regional Fisheries Board

Central Fisheries Board

Compass Informatics

Table of contents

Assessment of the Risk of Barriers to Fish Migration in the Nore Catchment

Assessment of the risk of in-river barriers to fish migration, on a case study basis in the River Nore (Southern Regional Fisheries Board area), which can be used subsequently as a mechanism to assess the risk of river barriers to fish migration nationally.

Foreword

Morphological pressures can impact ecology by direct loss of habitat or changes to sedimentation/siltation regimes. In Ireland and Northern Ireland the initial characterisation and analysis of water bodies in the 8 RBDs under Article 5 of the Water Framework Directive identified morphological pressures for placing 1720 (or 38.5%) of river water bodies at risk or probably at risk of failing to achieve their Water Framework Directive (WFD) status objectives. This process considered the following activities:

- channelisation, dredging and river straightening,
- flood protection and embankments,
- impounding,
- water regulation; and
- intensive land use.

Whilst the extent of these activities has been identified during the initial characterisation risk assessment, morphological quality is not systematically monitored in Irish rivers and lakes so there remains uncertainty as to the actual significance of these morphological pressures.

A Freshwater Morphology Programmes of Measures and Standards (POMS) Study was initiated in November 2005 to undertake this investigation and to develop a morphological assessment methodology for Irish Rivers. This POMS Study is administered through the Shannon International River Basin District Project by the Contracting Authority, Limerick County Council.

The primary objective of the study is to resolve the uncertainties identified in Ireland's Article 5 report in relation to the two key freshwater morphology assessments - channelisation and intensive land use, which together contributed to 84% of river water bodies being categorised as 1b: Probably At Risk. A secondary objective is to develop a management framework and assessment method with respect to freshwater morphology so that rivers and lakes can be monitored and classified, alterations to rivers and lakes can be managed and controlled, and steps taken to ensure the physical condition of rivers and lakes can support Good Ecological Status.

The present study was carried out under Work Package 7 – *Barriers to Migration* - of the national Freshwater Morphology Programme of Measures and Standards studies. The significance of fish as a biological indicator of morphological quality is widely recognised. The objective of *Work Package 7* is, by using an extensive data set on the distribution of artificial and man-made barrier throughout the Nore system, to assess the risk of delaying or preventing salmon and other fish migration which can adversely impact on the status of the water body.

INTRODUCTION

Under Article 5 (1) of the WFD there is a requirement for Member States to carry out, for each River Basin District, *"a review of the impact of human activity on the status of surface waters and groundwaters*". The identification of significant morphological alterations to waterbodies is listed in Annex II of the WFD as a specific pressure which had to be addressed in the risk assessment.

In accordance with the WFD, Good Status for surface waters is defined as: *Good Ecological Status plus Good Chemical Status.* Ecological Status comprises the following elements:

- Biological elements
- Chemical and physico-chemical elements supporting the biological elements
- Hydromorphological elements supporting the biological elements

More specifically, morphological elements supporting the biological elements include river depth and width variation; structure and substrate of the river bed; and structure of the riparian zone. Alterations to these conditions constitute human impact on the status of surface waters. In the WFD, hydromorphological elements contribute to status classification, only to distinguish between high and good ecological status. However, knowledge of a waterbody's hydromorphological conditions, regardless of status is important for the following reasons:

- For analysis and investigation into why waterbodies fail to reach good ecological status and what direct (river management) and indirect (catchment management) practices are required to lead to improved status;
- To prevent the deterioration in ecological status of a waterbody;

River Continuity is a very important element of hydromorphology which is a requirement under WFD. It is in this context that barriers to fish migration are being assessed. The absence or reduced abundance of fish species due to barriers will result in reduced fish status. In the Republic of Ireland drivers with the potential for causing pressures on morphological conditions were identified for rivers and lakes.(Anon, 2005).

Morphological Drivers Exerting Pressure on Rivers - RoI

Morphological Driver	**Description**
Channelisation and dredging	Silt and substrate removal for bed slope, side slope and depth of flow changes to the channel

	for drainage purposes.
Flood protection and embankments	The protection of lands adjacent to the water body from flooding by the presence of built embankments comprised of river bed and other material.
Impounding	**Backing-up of water through the presence of constructed dams.**
Water regulation	**Regulation of water flow through the introduction of locks, weirs, sluices.**
Intensive land use	Peat extraction areas, coniferous forests, arable land, urban areas.

Datasets relating to each of these activities were collected by the Shannon RBD from various authorities throughout RoI and NI. The Article 5 morphological risk assessment involved applying a set of thresholds to the pressure datasets, where each threshold defined a specific risk category.

A two stage approach was implemented. Stage 1 involved the determination of risk magnitude and Stage 2 was an adjustment based on data confidence. Risk magnitude of an individual waterbody was divided into four categories:

- (1a) – At risk of failing to meet WFD objectives by 2015
- (1b) – Probably at risk of failing to meet WFD objectives by 2015
- (2a) – Probably not at risk of failing to meet WFD objectives by 2015
- (2b) – Not at risk of failing to meet WFD objectives by 2015

The risk category of each waterbody was determined by taking the worst case from a range of pressure assessments and was reported to the European Commission in March 2005. Morphology pressures were identified across many Member States as exerting significant pressures which might result in waterbodies failing to achieve their WFD status objectives (Source H Bloech WFD Conference, Budapest, May 2005). Within RoI's Article 5 Report, freshwater morphology pressures accounted for placing 1720 (or 38.5%) of river waterbodies "at risk (1a) or "probably at risk (1b)" and 135 (or 18.1%) of lake waterbodies "at risk (1a)" or "probably at risk (1b)". The morphological activities resulting in "at risk" or "probably at risk" categorisation were;

- Channelisation
- Intensive Land Use
- Flood Protection
- Water Regulation
- Impoundments.

This study set out to determine the risk of impoundments or barriers to fish migration as a morphological pressure in one specific catchment (Nore) which can then be used in the Shannon River Basin District, Freshwater Morphology, Programmes of Measures and Standards (POMS) Study as a means of assessing such risks nationally.

Under the WFD there is a national remit to collect data on all barriers and to carry out an assessment of their impact on fish migration and on other biota. This information is required for the WFD but would also be extremely relevant for Habitats Directive species and would have major uses for the management of many different species and habitats.

The species currently being considered is salmon and the impact of barriers on this species. Barriers assessed in the filed as moderate or high risk to salmon migration were electro-fished to determine the presence of juvenile salmon upstream. A GIS analysis was then undertaken to re-classify barriers under a rule based system. Some assessment is also undertaken for eel and sea lamprey but not based on the field assessment of barriers.

A mechanism is set out to undertake the risk assessment for all relevant fish species. Any future study should consider the lowest common denominator species (i.e. the species which is least likely to traverse any of these barriers) and risk assess for that species. The upstream migration of lamprey is likely to be most affected and it may be the most suitable species on which to base the assessment. Risk assessment should also be undertaken for all Habitats Directive Annex 2 species recorded in Ireland (three species of lamprey, two species of shad and salmon in freshwater). The European eel (for which an EU recovery plan is required) and all other fish species which migrate or attempt to migrate through barriers (to spawn, to feed etc) should also be the subject of any future study.

Previous Studies of Barrier Impact on the Nore Catchment

O'Grady & Sullivan (1994) carried out a fishery survey on the Nore catchment in 1990 and field operations were completed in 1992. Juvenile salmonid and adult stocks were assessed throughout the catchment to identify the degree to which physical and biological factors were limiting fish production. The report identified for the first time many man-made physical barriers (weirs and bridge sills) which were prohibiting or severely limiting salmon access to a number of potentially productive spawning and nursery zones. Development proposals were made including bankside enhancement, removal of derelict weirs, provision of fish passes and shrub pruning programmes.

A report by Alan Sullivan, BSc. (Sullivan, 2007) was undertaken in 2007 on the assessment of fish passage and the ecological impact of migration barriers on the Nore catchment. He undertook prioritisation to rank sites based on;

- impact on species and life stage passability
- impact on habitat quality and quality of habitat upstream of barrier
- loss of habitat through ponding
- cost of repair and barrier condition

For each barrier location, the four ranking criteria were entered into a prioritisation spreadsheet and the total scores computed. This was a similar approach to that taken in the current study in that the presence of fish relative to barriers was included and an assessment of habitat quality was also undertaken. The difference in approach in this current study is that all potential barriers to migration (508 in total) throughout the Nore Catchment were assessed while Sullivan (2007) concentred on the major weirs and barriers (24 sites) on the main channel and tributaries. Sullivan (2007) did recommend undertaking electro-fishing surveys to determine the status of fish stocks above and below barriers and this approach has been taken in the present study. In the current study, the initial field based assessment of barrier risk is then re-assessed based on the presence of juvenile salmon and potential salmon spawning habitat upstream and barriers are re-classified after GIS analysis. This provides a risk based assessment.

The Nore Catchment

The river Nore is a significant salmon river of about 90 miles in length which rises in Co. Tipperary and flows through Co. Laois and Co. Kilkenny before joining the river Barrow. It is designated as a salmon river and is an SAC for salmon under the EU Habitats Directive. The Nore has a salmon conservation limit of 11,958 salmon and has had a recorded salmon rod catch of close to one thousand salmon over the past decade.

The wetted area study (Mc Ginnity *et al* 2003) published by the Central Fisheries Board quantified the surface area of all Ireland's salmon rivers. The Nore catchment was shown to have 6,796,230 M2 of riverine habitat, or 6% of the national total, the fourth largest of Ireland's 148 salmon rivers. This report also undertook an assessment of the extent of salmon anadromy within catchments. No barriers to salmon anadromy were identified for the Nore catchment and the accessible fluvial habitat was deemed to be the total fluvial habitat. The results of the current study will provide new data to assess the extent of accessible habitat throughout the catchment.

Introduction to the Current Study

A barrier impact assessment case study was initiated in 2007 in the Nore catchment using field data collected by the Southern Regional Fisheries Board. The purpose of the Nore study is to assess the risk of in-river structures to the timing and success of salmon migration. The Southern Board has compiled an extensive data set on the distribution of artificial and man-made barrier throughout the Nore system. A system is required so that this information can be used to assess the risk of delaying or preventing salmon and other fish migration which can adversely impact on the status of the water body.

The overall objective of the study is to relate the distribution of juvenile salmon and/or the location of potential salmon spawning areas to the barrier information to allow assessment of the degree to which specific barriers are impeding the upstream passage of salmon. Groud-truthing of barrier impact by rapid assessment (electrofishing) to determine the relative abundance of juvenile salmon is central to the risk assessment. When this assessment has been undertaken, it will be possible to assess the risk of a barrier to impeding salmon migration and to use the CFB wetted area database to allow assessment of the benefit of removing a particular barrier and allow calculation of the

additional wetted area to be gained. This will provide input for the development of a barrier risk assessment scheme by the WFD group.

Methodology

A number of datasets were of relevance to achieving the study objective:

1. Obstruction / Barrier Classification by SRFB Staff

A total of **508** in-river structures were examined by SRFB staff as potential barriers to salmon migration throughout the Nore catchment. Data was compiled on a survey sheet, (Appendix 1). The location of obstructions was recorded along with the nature of the obstruction, (table 1) natural (rock/bedrock) or manmade and then the nature of manmade obstructions .i.e bridge apron, weir, etc in addition to many river channel physical features. Based on the type and nature of the obstruction, an assessment was then made by the fishery officer regarding the risk of the obstruction preventing adult salmon passage upstream. The risk categories were;

- *no risk*
- *low risk*
- *moderate risk*
- *high risk*
- *impassable*.

Each obstruction was then coded based on the risk category assigned, (fig 2). The location of natural and manmade barriers is set out, (figure 3).

Table 1. Nature of obstruction and material type.

Nature of Obstruction

BA	Bridge Apron
W	Weir
RB	Rock/Bedrock
C	Culvert
F	Ford
HS	Hydro-electric scheme
BNA	Bridge no Apron
O	Other

Material Type

MC	Mass concrete
M	Masonary (Stone)
R/B	Rock/Bedrock
FM	Ford Material
T	Timber
NBM	Natural Bed material

O	Other

2. Potential Salmon Spawning GIS layer

The distribution of spawning gravel for potential salmon spawning areas throughout the Nore catchment was mapped on GIS from information provided by Southern Regional Fisheries Board staff. This included known salmon spawning areas from direct observation and potential salmon spawning areas due to the presence of suitable gravel areas.

The degree of risk of any particular barrier to preventing the upstream movement of salmon can then be assessed relative to the potential for salmon spawning. The assumption used in this study was that no potential for salmon spawning above a barrier would therefore confer no risk to preventing upstream salmon movement for spawning.

3. Juvenile Salmon Database

Once each obstruction was categorised during the field survey with regard to the degree of risk of preventing adult salmon upstream movement, electro-fishing was undertaken in 2008 above all obstructions classified as moderate or high risk, (fig 3). The presence or absence of salmon fry (0+ fish) and salmon parr (≥ 1+ fish) was recorded. The CFB national juvenile salmon database containing historical information (1990 – 2007) on the distribution and abundance of juvenile salmon throughout the Nore catchment was also used, (fig 4).

An interrogation of the distribution of juvenile salmon relative to the field classification of barriers by SRFB staff would then allow determination to be made of the actual risk of each obstruction restricting upstream movement.

4. CFB Wetted Area Database

A study undertaken nationally in 2003, the "Quantification of the Freshwater Salmon Habitat in Ireland", Mc Ginnity *et al*, 2003, quantifies the amount of wetted area in the Nore catchment. The Nore is the fourth largest salmon river in Ireland with 6,796,230 square metres of surface area available, 6% of the national total.

When the risk of each obstruction restricting upstream salmon escapement has been assessed, the CFB wetted area database can be used to demonstrate the benefit of removing a particular barrier and allow calculation of the additional wetted area to be gained.

5. Rules based system

A GIS based analysis of the distribution of barriers mapped with reference to the available GIS datasets has been performed in a step-wise manner:

- geo-location of barriers on GIS river network
- assessment of whether the barrier location is 1) on a small tributary (Strahler 1st order) or 2) on a steep reach (4%)

- assessment of upstream spawning reaches and electro-fishing data to determine potential risk posed by barrier
- calculation of 'wetted area' fluvial habitat base and amount of spawning area upstream of barriers – potential gain if barrier removed
- calculation of upstream habitat base and spawning area that is in turn made inaccessible by further upstream barriers – to determine net habitat gain limitation if further upstream barriers remain intact

5.1 Verification of barriers locations on river reaches

The barriers dataset developed by SRFB for the Nore contains some 503 barriers. Inter alia descriptors for the barriers include GPS derived easting and northing location coordinates and river tributary and townland names. Initial placement of barriers in the GIS based on the coordinates provided indicated an anomaly in some cases – either a barrier coordinate placed the feature at a remove from any river or the location provided was very close to a confluence whereby assignment to the correct tributary or downstream element could be in error.

A verification protocol was established that 'snapped' each barrier to the most apparent location on the river network as an initial stage based on the initial coordinates. GIS layers indicating these barrier locations and 'link lines' to visualise the barrier location on the GIS river network arising from the snapping process were provided to SRFB for verification or adjustment. Updated locations were provided back to Compass to complete the barrier location process which included determination of the exact location of the barrier on the river segment in the GIS (measured as a distance in metres along the river segment from the start, i.e. u/s point).

5.2 Reach type

The EPA/ CFB GIS river network contains basic attributes to describe the local reach characteristics. The stream gradient (determined with reference to the EPA DTM) attribute has been used to identify barriers on streams with a gradient > 4%. Fish stock abundance data indicates that salmon are not recorded at gradients greater than 4%. Strahler stream order classification has been used to identify small '1st order' streams likely to have insufficient width for salmon utilisation.

5.3 Comparison of provisional barrier risk category against fish distribution data

Fish distribution patterns were assessed in the context of electro-fishing records and spawning areas. This included known salmon spawning areas from direct observation and potential salmon spawning areas due to the presence of suitable gravel areas.

Electro-fishing data collected by the SRFB and CFB was utilised to map the distribution of the salmon stock within the Nore catchment. This contained survey records form the period 1990 – 2008. In a manner similar to the original barrier datasets a verification procedure was carried out to confirm the correct location of the electro-fishing sites and the survey sites were thereafter recorded at an exact location along the relevant river segment through a linear referencing method.

The barrier dataset contained a provisional field based risk assessment to salmonid migration with the risk categories – Impassable, High, Moderate, Low, No Risk. These provisional risk scores

were based on SRFB knowledge and on-site assessment. The availability of electro-fishing data and mapping of spawning areas has been used to re-classify the barriers such that:

Table 2. GIS Risk Assessment Criteria

Field Based Assessment	Spawning potential u/s	Presence of 2 yr classes	Presence of 1yr class	Absence of juveniles	GIS risk assessment
High	No	Yes/No	Yes/No	Yes/No	None
High	Yes	Yes	/	/	Moderate
High	Yes	/	Yes	/	High
High	Yes	/	/	Yes	High
Moderate	No	Yes/No	Yes/No	Yes/No	None
Moderate	Yes	Yes	/	/	Low
Moderate	Yes	/	Yes	/	Moderate
Moderate	Yes	/	/	Yes	High
Low risk	No	Yes/No	Yes/No	Yes/No	None
Low risk	Yes	Yes	/	/	No risk
Low risk	Yes	/	Yes	/	Moderate
Low risk	Yes	/	/	Yes	High risk
No risk	No	Yes/No	Yes/No	Yes/No	None
No risk	Yes	Yes	/	/	No risk
No risk	Yes	/	Yes	/	Moderate
No risk	Yes	/	/	Yes	High risk

- the Risk posed by barriers without upstream spawning areas is assumed to be 'None'
- (it is recognised, however, that there will be some loss of potential juvenile productive capacity if juvenile salmon spawned downstream migrated above a barrier, see discussion)

  where there are upstream spawning reaches and electro-fishing evidence of the presence of both salmon Fry and Parr the risk is downgraded to the next lower level. This is undertaken as it is the presence or absence of salmon fry and parr which is used rather a relative abundance rating and this approach is therefore more precautionary.

- where there are upstream spawning reaches but no electro-fishing evidence of salmon Fry or Parr the risk is assumed to be 'High'

- where there are upstream spawning reaches but electro-fishing evidence of the absence of either Fry or Parr the risk is assumed to be 'High' for barriers classified by field assessment as high. For classified by field assessment as moderate, low or no risk, the absence of either fry of parr means these barriers are all classified as moderate.

- Field Based risk scores of Impassable, Moderate or Low retained post GIS analysis indicate sites where u/s spawning exists but no electro- fishing records available to confirm fish stock status

5.4 Estimation of Wetted Area' Habitat Availability

The CFB study, “Quantification of the Freshwater Salmon Habitat in Ireland” ,Mc Ginnity *et al*, 2003, quantifies the amount of wetted area for Irish river systems including the Nore catchment. This is based on a statistical model that relates GIS derived factors (particularly catchment area and stream link magnitude (Shreve, 1966)) to measured channel width at some hundreds of locations across Ireland. The model thereafter allows estimation of channel width on any reach where the catchment area and stream link attributes have been recorded. Width is assumed to be consistent along each reach (recorded in the GIS as a river section between a pair of confluences or ‘river segment’) whereby the standard width * reach length provides an estimate of wetted area.

In the first instance the ‘wetted area’ habitat database for the Nore has been used to calculate the wetted area upstream of barriers with a Risk value of ‘High’ or ‘Impassable’. In addition the length of spawning channel u/s of the barrier is calculated.

In a secondary analysis other barriers with a Risk score of ‘High’ or ‘Impassable’ that lie upstream of the target barrier are assessed. The most downstream of these barriers, i.e. those that would pose the next blockage to migration in an upstream direction are identified and the sum of the wetted area and spawning channel length associated with these is recorded. The difference between the u/s wetted area and spawning length associated with the target barriers and the wetted area and spawning length associated with the next upstream group provides an estimate of the net gain in wetted area or access to spawning channel associated with removal of the target barrier alone.

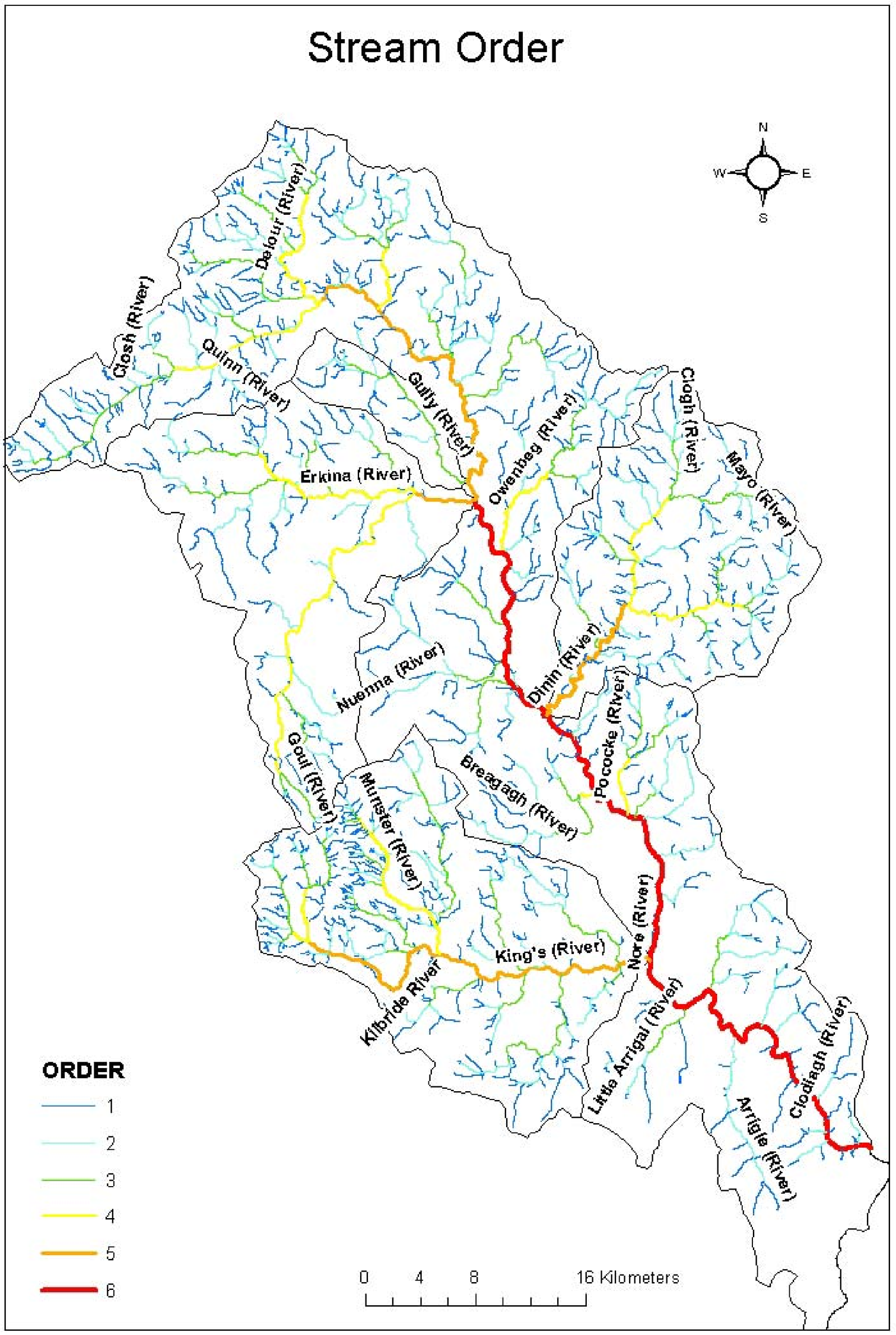

Fig 1. Stream Order in the Nore Catchment

RESULTS

The length of channel and the quantity of wetted area in the Nore catchment by stream order is set out (able 3) along with the length of spawning channel by stream order. The majority of known or potential spawning is in 3rd and 4th order streams. Sections of the main channel (6th order) do contain spawning gravel and salmon are known to spawn on the main channel but an assessment was not possible due to excess water height.

Table 3. Nore Catchment Summary Statistics

Length of Channel	Stream Rank	Length km-1	Wetted Area ha2
	Total	2247	866
	6th order	55	205
	5th order	82	150
	4th order	138	127
	3rd order	312	171
	2nd order	529	122
	1st order	1131	91
	Order > 1, gradient > 4%	31	4.7
Length Spawning channel	Total	152.2	
	6th order	0.1	
	5th order	11.2	
	4th order	52.9	
	3rd order	58.7	
	2nd order	24.7	
	1st order	4.6	

Table 4 lists the categories of barrier placed into classes at the field survey stage. A total of 11 natural and 497 artificial barriers were surveyed, (fig 3).

Table 4. Summary of Barrier Field Survey

Barrier Type	SRFB Risk Group	Count
Natural	Total	11
	Impassable	3
	High	6
	Moderate	1
	Low	1
Artificial	Total	497
	Impassable	46

	High	76
	Moderate	61
	Low	183
	No risk	131

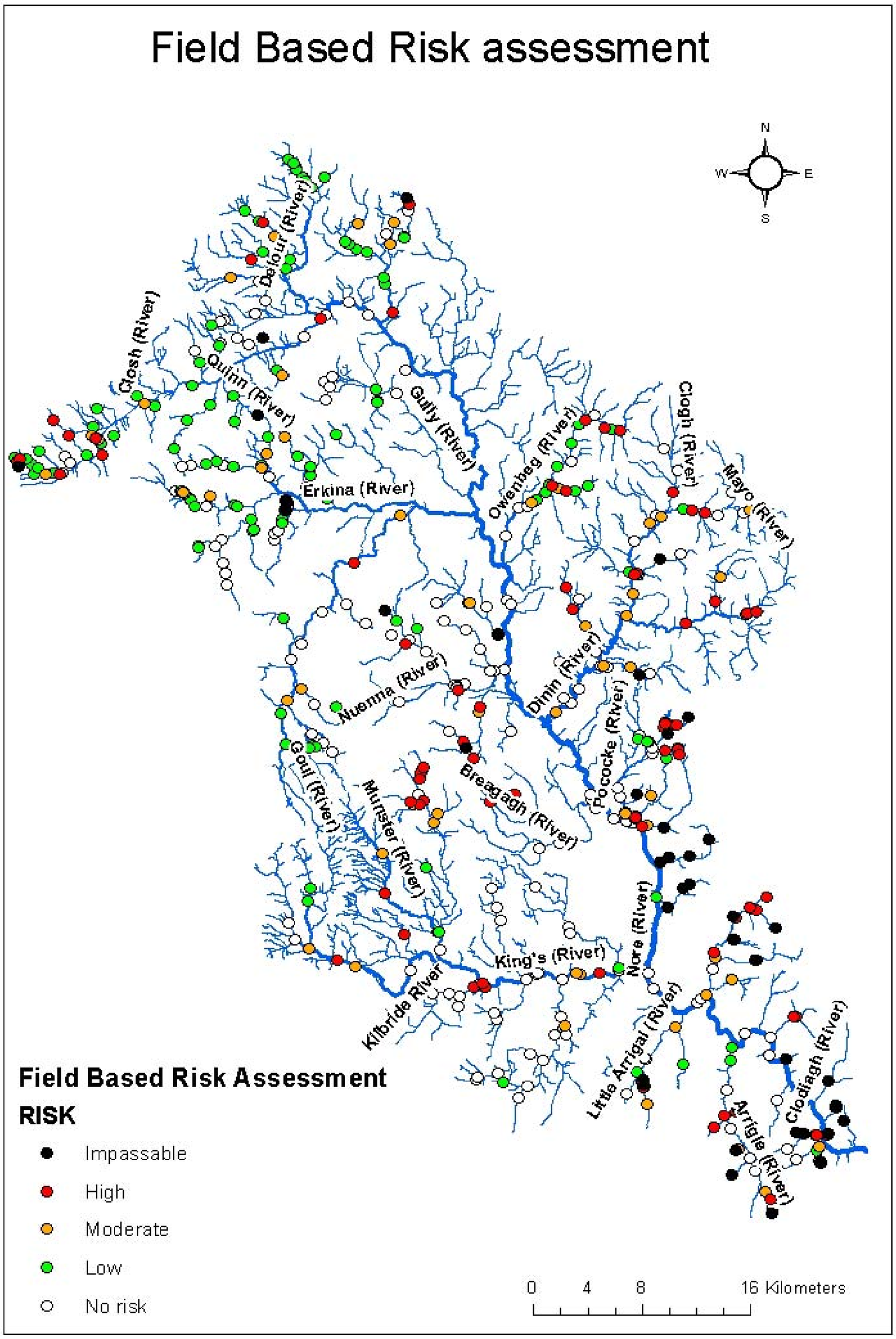

Figure 2. Field Based Risk Assessment of Barriers

The number of natural barriers in each category with spawning and presence of salmon fry / parr upstream (table 5) and the location of natural and artificial barriers (figure 3) are shown.

Table 5. Summary of Natural Barrier Analysis

Barrier Type	SRFB Risk Group	Count	No with u/s spawning	No with u/s Salmon Fry-Parr
Natural	Total	11	4	0
	Impassable	3	0	0
	High	6	4	0
	Moderate	1	0	0
	Low	1	0	0

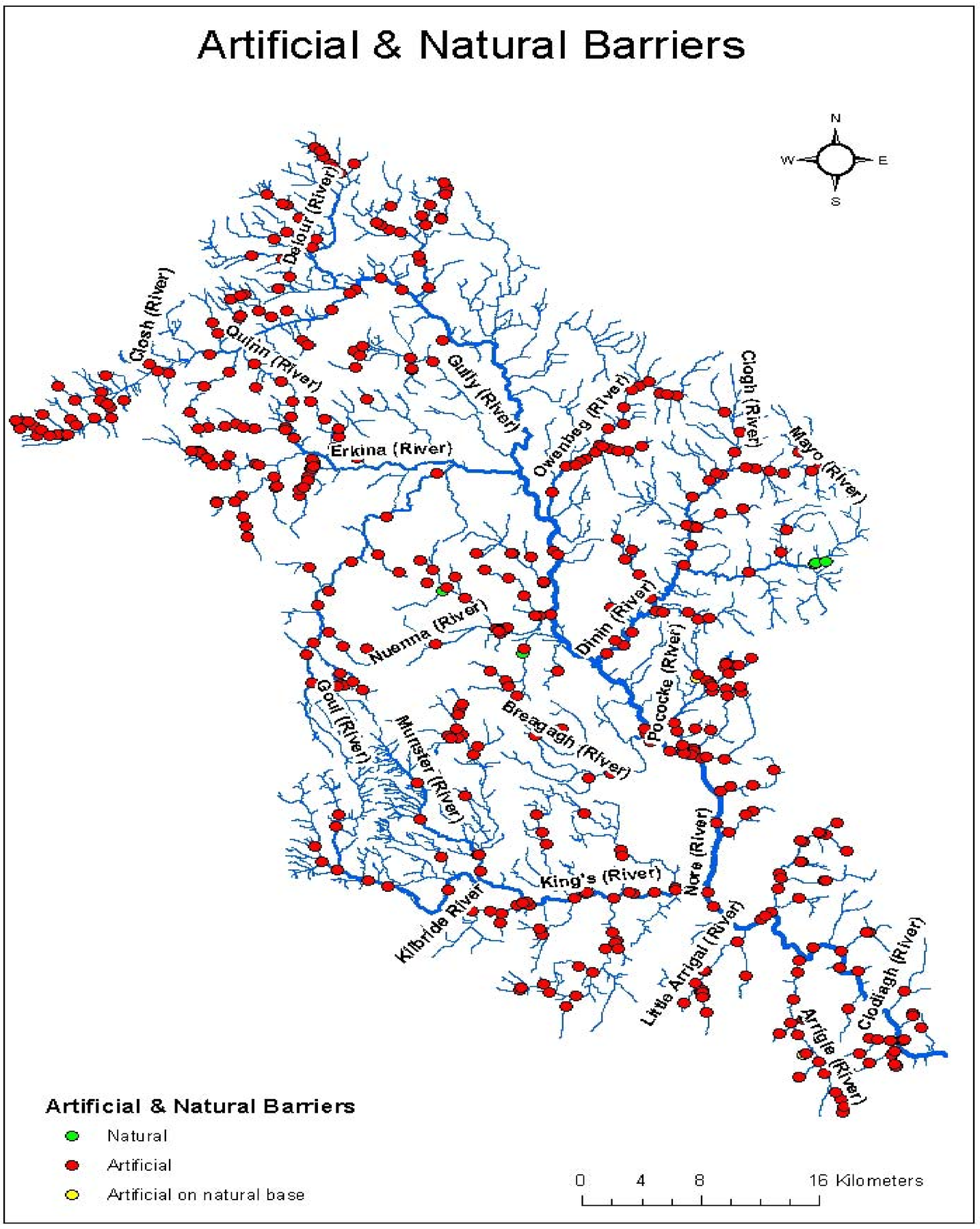

Fig 3. Location of natural and artificial barriers

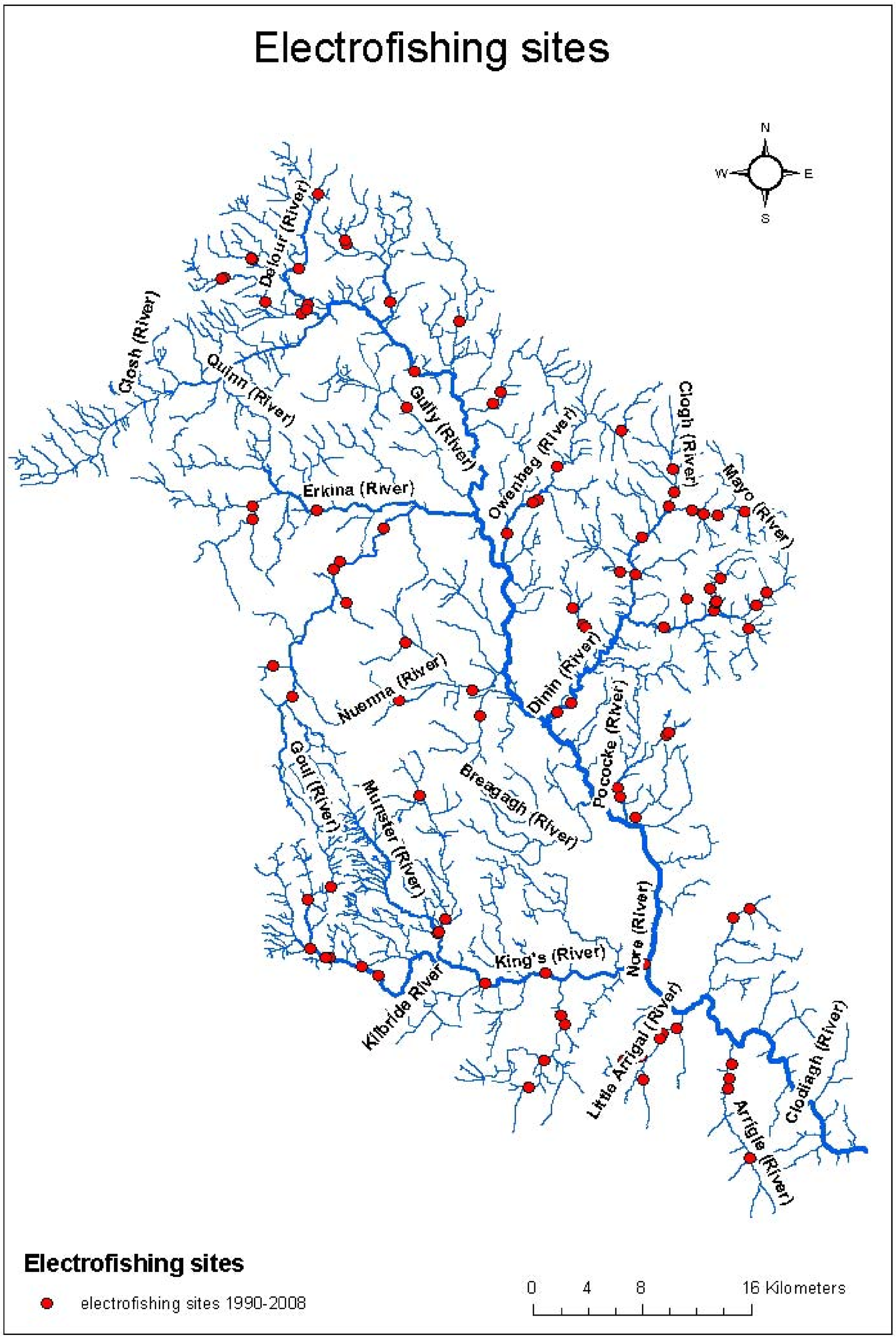

Figure 4. Location of electrofishing sites 1990-2008

Table 6 sets out the number of barriers placed in each risk category after Southern Board field survey analysis. Barriers are then re-classified based on GIS analysis using data on presence / absence of juvenile salmon, presence of spawning areas, and use of 1st order stream data and gradient data (>4% gradient). Of the 46 barriers classified by field survey as impassable, only one barrier was deemed impassable based on the criteria set out, Figure 5. This would have been a combination of absence of spawning gravel upstream, gradient > 4% or barrier on a 1st order stream.

Table 6. Summary of Artificial Barrier Analysis

Barrier Type	Risk Group	SRFB Field Analysis	GIS Analysis
Artificial	Total	497	497
	Impassable	46	1
	High	78	10
	Moderate	61	27
	Low	129	16
	No Risk	183	57
	None		386

Three year classes of juvenile salmon

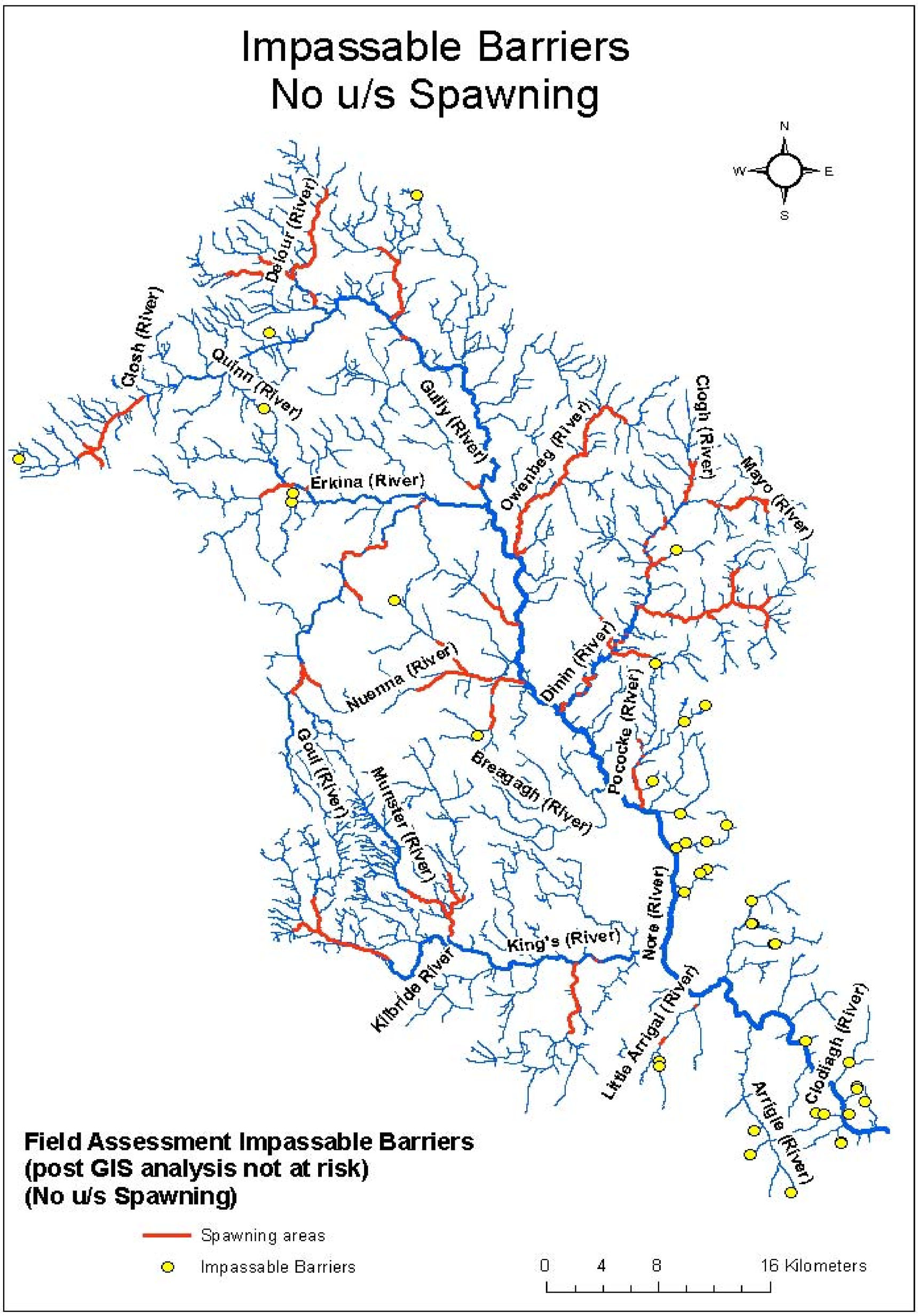

Figure 5. Field Assessment Impassable Barriers not at Risk after GIS analysis

Figure 6 sets out the risk of all barriers to migration after the risk assessment undertaken. Of the 78 barriers classified as high risk, this number reduced to 10 after the risk assessment process undertaken. The remaining 10 barriers were deemed high risk as there was spawning potential upstream. Risk assessment resulted in 61 barriers classified as moderate by field assessment being reduced to 27 after risk assessment, (fig 7).

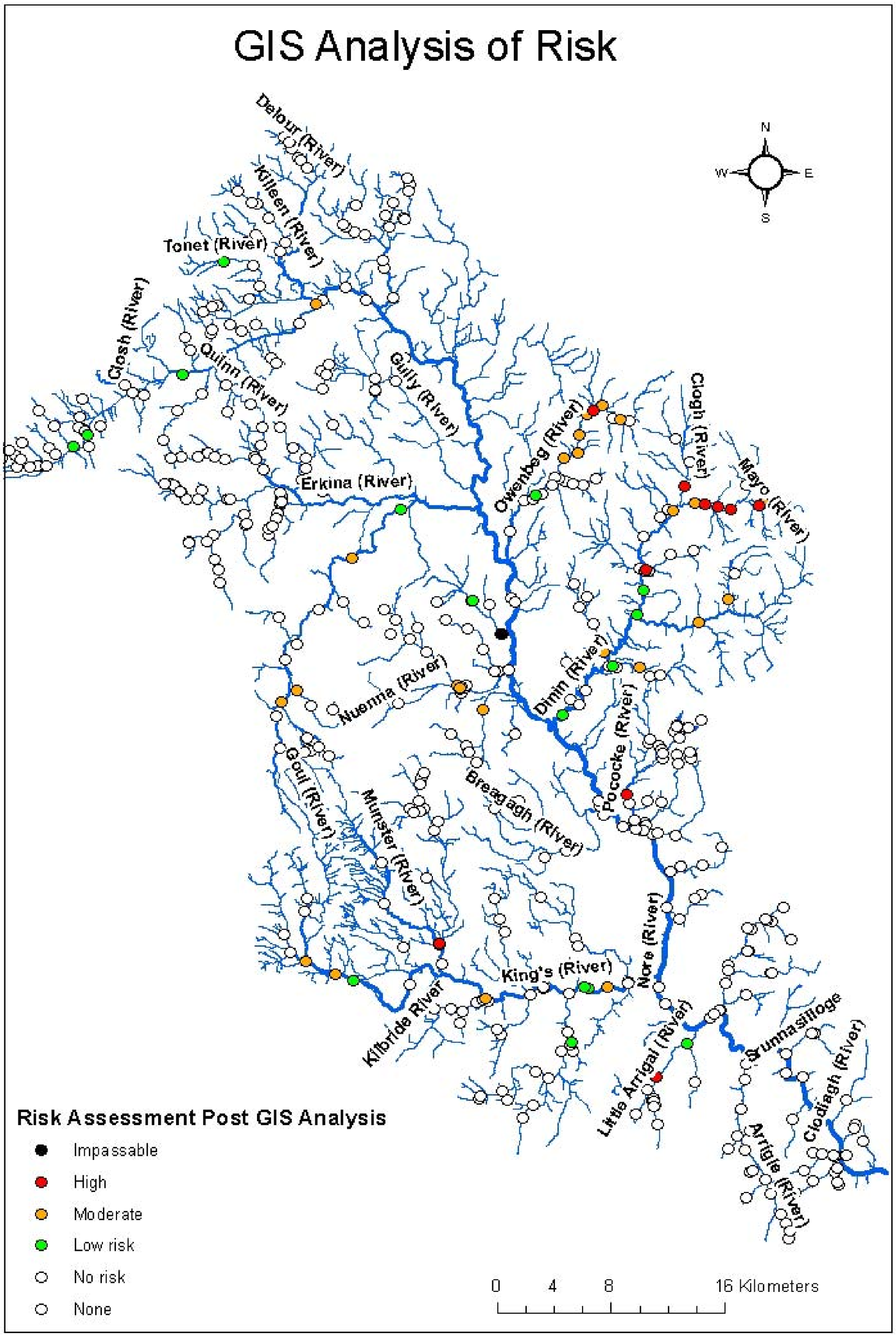

Figure 6. Risk Assessment of all Barriers post GIS analysis

Re-Classification of Barriers after GIS Analysis

Based on the criteria set out in Table 2 (Rules based system) barriers are re-classified after GIS analysis. The following classification was made based on barriers with spawning potential

upstream. If salmon fry and parr were absent above a barrier, the barrier was re-classified as high risk. If salmon fry and parr were present upstream of a field assessed high risk barrier, the barrier was down graded to a moderate risk barrier. If both year classes were present upstream of a moderate or low risk barrier, the barrier was re-classified as low and no risk respectively. A no risk barrier would remain no risk after GIS analysis. If one juvenile salmon year class was present u/s of a high risk barrier, it remained classified as high risk. If one year class was found upstream of a moderate, low or no risk barrier, the barrier was reclassified as moderate risk.

Although the presence of one year class of juvenile salmon above a barrier may indicate that a barrier may be inhibiting the upstream migration of salmon in certain years there are a number of other factors which may be responsible. The habitat sampled upstream may not be suitable for a certain life stage or migration of parr down stream in small channels <4m in times of low water may also be a factor. Inadequate water quality may also have an impact on the presence of a salmon year class. Finally, the electrofishing technique in 2008 concentrated on riffle areas and therefore is more likely to capture salmon fry than parr.

After GIS analysis, twenty seven barriers were re-classified as moderate risk, (table 8, fig 7). These moderate barriers were primarily located on the Dinan, Kings river, Owenbeg and Nuenna. Further investigation of these barriers is required to confirm their status with regard to the risk of inhibiting the upstream migration of salmon.

The location of impassable (1) and high risk (10) barriers after GIS risk assessment are set out in Table 7, (fig 8). These barriers constitute candidate barriers for removal that would yield gain .i.e access to spawning areas and additional wetted area. The Dinan tributary has the largest number of high risk barriers in the Nore catchment. These barriers need to be re-examined.

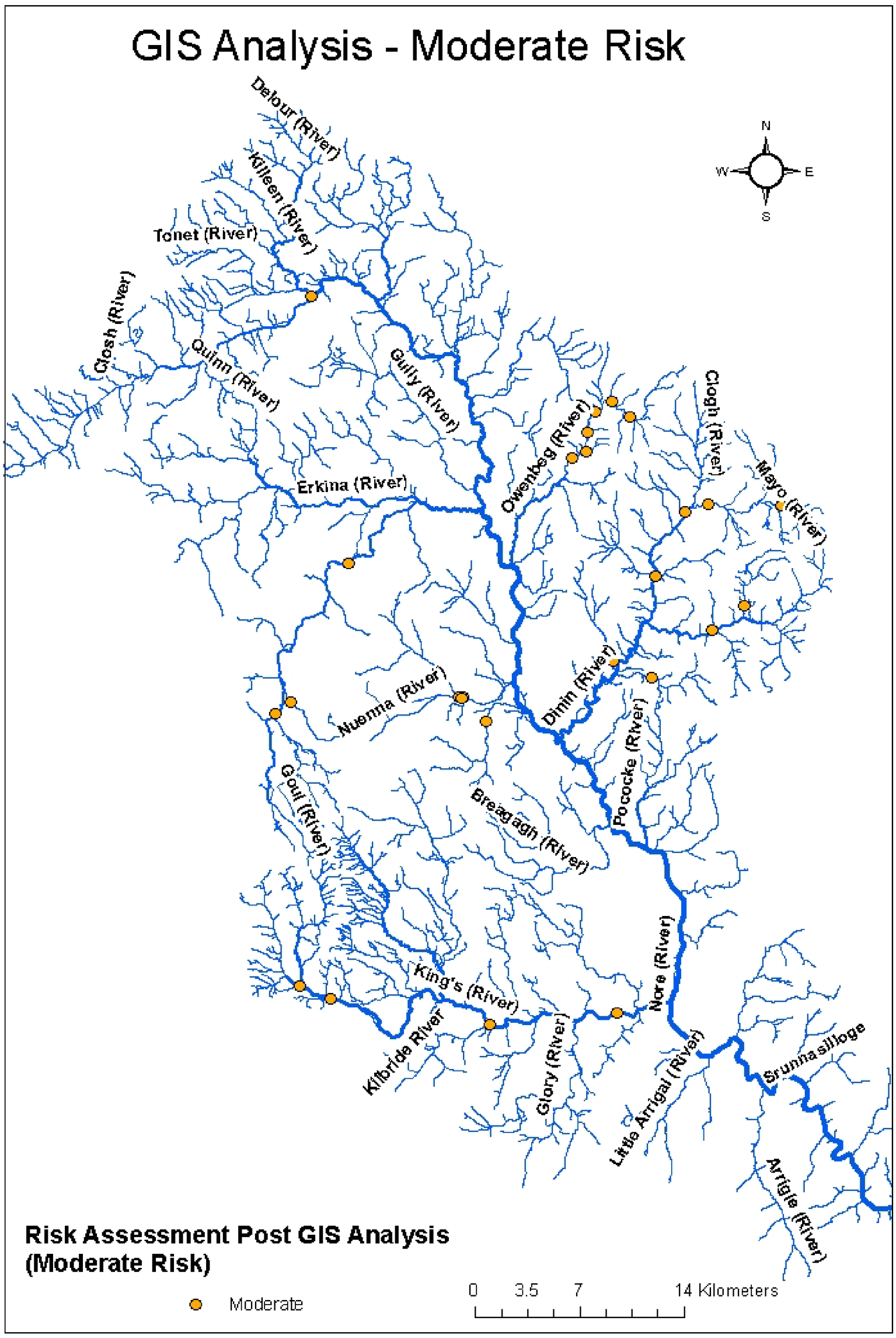

Figure 7. Risk Assessment of Barriers Post GIS analysis classified as Moderate Risk

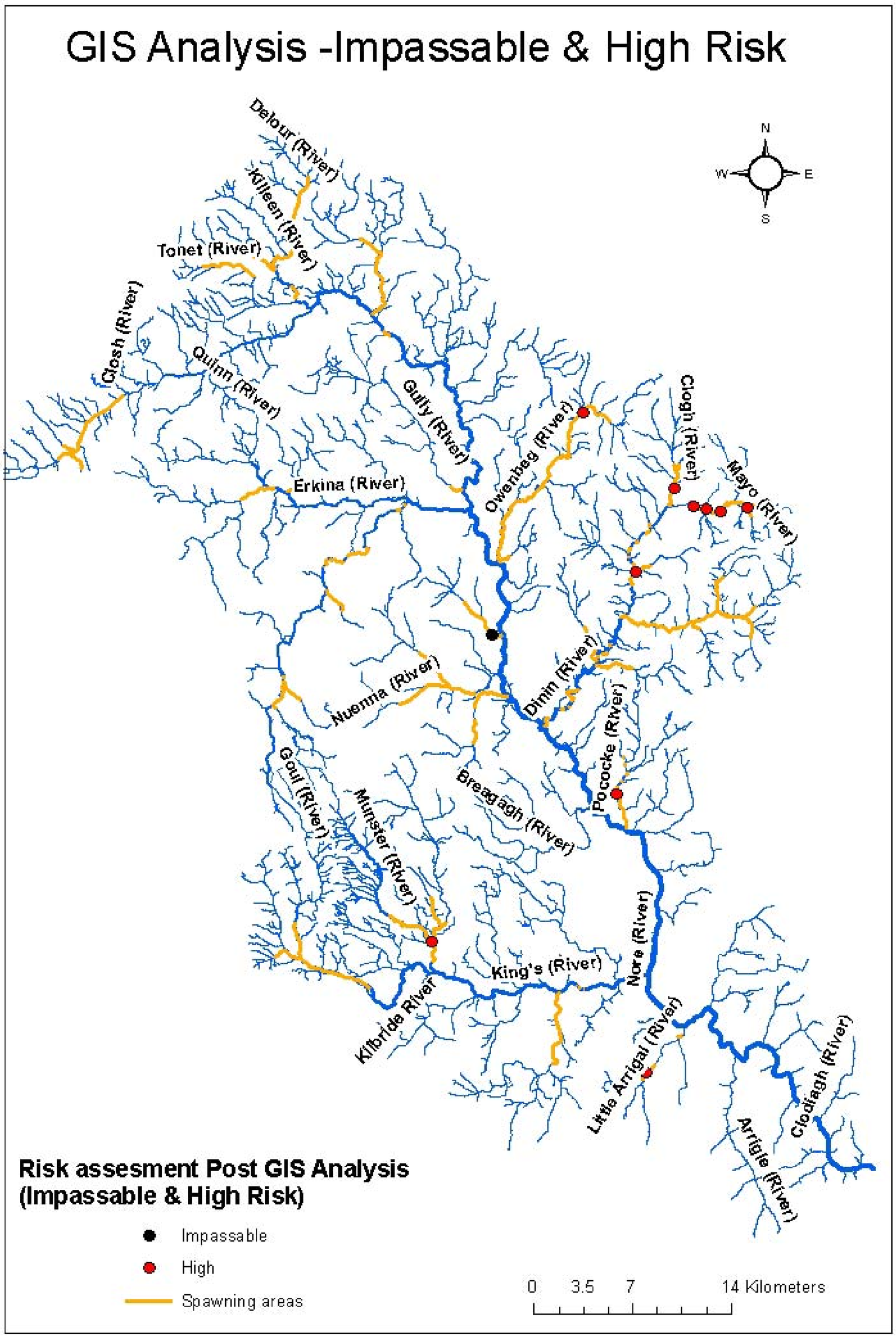

Figure 8. Assessment of High Risk and Impassable barriers after GIS Analysis

Table 7. GIS Analysis of Impassable & High risk Barriers

Barrier code	Nature (SRFB Assessment)	Tributary	Eastings	Northings	GIS Barrier Risk	u/s Fry Present (sites)	u/s Fry Absent (sites)	u/s Parr Present (sites)	u/s Parr Absent (sites)	Wetted Area u/s of Barrier (ha)	Wetted Area u/s of u/s barriers (ha)	Wetted Area % gain	Spawning Channel u/s (m^{-1})	Spawning Channel u/s of u/s barriers (m^{-1})	Spawning % gain	Field based Assessment
15_236	BA	Munster (trib)	239205	146719	High	1	1	0	2	15	15	100	4168	4168	100	Low
15_398	BNA	Dinin (Killeen) Br	259780	177400	High	0	2	0	2	6.6	5.9	90	3882	3265	84.1	High
15_118	W	Lisdowney	243551	168624	Impassable	0	0	0	0	3	3	100	2587	2587	100	High
15_38	BA	Dinin (Clogh)	256520	179050	High	0	2	1	1	6	6	100	2195	2195	100	High
15_5	W	Dinin (MC)Castlecomber weir	253780	173096	High	0	9	3	6	30.9	12.4	40.1	11511	2173	18.9	High
15_462	BNA	Pococke (MC)	252364	157267	High	0	3	0	3	6.3	6.3	100	1470	1470	100	No risk
15_42	BA	Dinin (Killeen)Ormonde	258844	177550	High	0	2	0	2	7.3	0.8	10.3	4783	901	18.8	No risk
15_77	BA	Owenbeg (MC)	250002	184388	High	0	1	1	0	5.7	1.4	25	2350	772	32.9	High
15_4	BA	Dinin (Killeen)Doonbeg Br.	257900	177736	High	0	4	1	3	9.2	1.9	20.4	5509	726	13.2	High
15_403	BNA	Dinin (Mayo)	261703	177623	High	0	1	0	1	0.7	0.7	100	617	617	100	No risk
15_387	BNA	Little Arrigle	254498	137344	High	0	1	0	1	1.6	1.6	100	362	362	100	No risk

Table 8. GIS Analysis of Moderate risk Barriers

Barrier code	Nature (SRFB Assessment)	Tributary	Eastings	Northings	GIS Barrier Risk	u/s Fry Present (sites)	u/s Fry Absent (sites)	u/s Parr Present (sites)	u/s Parr Absent (sites)	Field based Assessment
15_7	W	Kings (Bradleys weir)	251067	143665	Moderate	7	11	7	11	High
15_48	BA	Kings (Br u/s of Island Br)	231782	144571	Moderate	1	4	2	3	High
15_74	W	Kings (weir nr Drimeen)	242467	142881	Moderate	4	7	4	7	High
15_303	BA	Kings (Wilford Br)	229705	145505	Moderate	0	0	0	0	Moderate
15_293	BA	Dinin (Monavea)	262115	177810	Moderate	0	0	0	0	Moderate
15_294	BA	Dinin (Massford Br)	255640	177329	Moderate	0	7	2	5	Moderate
15_297	BA	Dinin (Douglas)	253340	166220	Moderate	0	0	0	0	Moderate
15_43	BA	Dinin	253639	172998	Moderate	1	9	4	6	High
15_507	BA	Dinin (Metal Br)	259604	171013	Moderate	0	0	0	0	High
15_508	BA	Dinin (Coan)	257455	169421	Moderate	0	0	0	0	High
15_399	BNA	Dinin (Gloshia)	250755	167320	Moderate	0	3	2	1	No risk
15_211	BA	Dinin (Killeen)	257198	177879	Moderate	0	4	1	3	Low
15_467	BNA	Owenbeg	248965	181400	Moderate	0	1	1	0	Low
15_471	BNA	Owenbeg	250666	184778	Moderate	0	1	1	0	No risk
15_233	BNA	Owenbeg	249564	184115	Moderate	0	1	1	0	Low
15_234	BNA	Owenbeg	247979	181022	Moderate	0	1	1	0	Low
15_240	BNA	Owenbeg	249019	182693	Moderate	0	1	1	0	Low
15_245	BNA	Owenbeg	251910	183716	Moderate	0	1	1	0	Low
15_304	O	Lisdowney	241500	170970	Moderate	0	0	0	0	Moderate
15_439	BA	Nuenna	240701	164887	Moderate	0	2	2	0	No risk
15_448	BNA	Nuenna	240390	164930	Moderate	0	1	1	0	No risk
15_458	BA	Nuenna	240596	164791	Moderate	0	2	2	0	No risk
15_218	BA	Nuenna	239035	166731	Moderate	0	1	1	0	Low
15_312	BA	Goul BR1	229118	164575	Moderate	0	0	0	0	Moderate
15_313	BA	Goul BR2	228025	163769	Moderate	0	0	0	0	Moderate
15_78	F/O	Goul	232966	173922	Moderate	3	2	4	1	High
15_506	O	Delour	230477	191856	Moderate	0	0	0	0	High
15_57	BA	Arigna	242236	163281	Moderate	1	0	1	0	High