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REVIEW OF THE SOUTH GALWAY FLOOD STUDY REPORT

ENGINEERING PROPOSALS FOR THE REINSTATEMENT OF CULVERTS ON THE N18 AND THE PROVISION OF NEW CULVERTS ON MINOR ROADS AT KILTARTAN

FEASIBILITY OF AN OVERLAND CHANNEL FROM COOLE TO KINVARRA

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Office Of Public Works,
Western Region Drainage Maintenance,
Headford,
County Galway.

Jennings O'Donovan & Partners,
Consulting Engineers, Finisklin, Sligo.
Tel: 071 - 9161416 Fax: 071 - 9161080
e mail: info@jodireland.com

JENNINGS O'DONOVAN & PARTNERS
Project, Civil and Structural Consulting Engineers,
FINISKLIN BUSINESS PARK,
SLIGO,
IRELAND.

Telephone (071) 9161416
Fax (071) 9161080

Email info@jodireland.com
Web Site www.jodireland.com

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	Prepared by	**Reviewed by**	**Approved by**
Document **DRAFT**	Name	Name	Name
Date	Signature	Signature	Signature

	Prepared by	**Reviewed by**	**Approved by**
Document **FINAL**	Name Pierre Mayol	Name Conor McCarthy	Name Conor McCarthy
Date 20/01/2011	Signature	Signature	Signature

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ENGINEERING PROPOSALS FOR THE REINSTATEMENT OF CULVERTS ON THE N18 AND THE PROVISION OF NEW CULVERTS ON MINOR ROADS AT KILTARTAN FEASIBILITY OF AN OVERLAND CHANNEL FROM COOLE TO KINVARRA

EXECUTIVE SUMMARY

INTRODUCTION & BACKGROUND

In November 2009 and particularly the first three weeks of the month, a number of weather events occurred which resulted in record rainfall and high water levels being recorded in many parts of County Galway, including Kiltartan which is part of the Slieve Aughty catchment. The dynamics of this catchment are significantly different than most river catchments encountered in Ireland as karstification is widespread, with 273 features recorded. Many swallow holes / sink holes can be seen at various locations where overground rivers are swallowed through large underground conduits and fissures. During the November 2009 flood, the capacity of the underground conduits was reduced and a significant amount of water found its way overground as the head differential between the main swallow hole at Kiltartan and Coole Lough was gradually reduced. In Kiltartan, it is understood that flooding was caused by the following sequence of events :

- Flow capacity of the underground system downstream from Kiltartan was exceeded (Coole Lough to Caherglassaun Lough to Kinvarra cave system)
- Water levels rose significantly at Caherglassaun Lough and then at Coole Lough
- The head differential between Coole Lough and the main sink hole at Kiltartan (known as Pollomuiri) decreased significantly which subsequently reduced the capacity of the underground system from Kiltartan to Coole
- Levels rose at Kiltartan and water found its way around the Coole ridge through a natural winter "overflow" channel at Corker.

This study, commissioned in July 2010 by the Office of Public Works (OPW), further investigates the November 2009 flood at Kiltartan, Coole Lough, Caherglassaun Lough and Kinvarra and identifies a range of drainage improvement works aimed at restoring natural winter "overflow" channels such as the Corker overflow. This includes the development of engineering proposals for the reinstatement of culverts on the N18 at Kiltartan and the provision of new culverts on the existing adjacent minor county Kiltartan to Raheen Road. This report also addresses the feasibility of an overland channel from Coole to Kinvarra as originally investigated under the April 1998 South Galway Flood Study Report. An overground condition survey of the key swallow holes in the area was also carried out for the purpose of locating key karstic features, potential flow restrictions / blockages and cleaning and maintenance requirements.

ENGINEERING PROPOSALS

Engineering Proposals for Restoration Works at Kiltartan

During the November 2009 floods, the existing culvert underneath the N18 road at Kiltartan was blocked and consequently flood waters rose above the level of the N18. As a result, the N18 was closed for a number of days as well as the adjacent Limerick to Galway railway. As part of emergency works in November 2009, the old culvert crossing the N18 was unblocked. A survey carried out in August 2010 as part of this study showed that this culvert is still partially blocked and could have sustained damages from the flow of water released following the November 2009 emergency works. This culvert was found to be capable of conveying a flow of 20 m^3/s. However, this is less than the flow capacity of $30m^3/s$ which is the estimated overground flow of the existing arch bridge located further downstream along the Corker overflow. This flow of $30m^3/s$ has been assessed to be the natural overground winter flow capacity in the area.

There is another crossing at the local Kiltartan to Raheen road which is located further downstream from the N18 crossing. This local road was raised following the 1995 flood event and two 150mm diameter overflow pipes were provided. These were not adequate to transfer excess flows as became clearly evident when water levels rose above the road in November 2009.

A survey was carried out at Corker as part of this study and an agricultural access road was found to cross the natural channel path halfway along the Corker overflow. A cross section approximately 25m long shows levels significantly higher than surrounding lands at Corker. This restricted the flow of water in November 2009.

The existing arch bridge located at the downstream end of the Corker overflow was found to be capable of conveying approximately 30 m^3/s. There are boulders located at both entries of the culvert and debris such as pieces of wood which could restrict the hydraulic capacity. This culvert was however found to be in good structural condition.

Construction of the new M18 from Gort to Tuam is expected to commence in 2011. The motorway will run perpendicularly to the general direction of the flow of water at Kiltartan. The road is proposed to follow the Coole ridge and then cross under the Kiltartan to Raheen local road before continuing on across the Corker area in a northerly direction. It is considered absolutely essential that the design of the new motorway take into account the water dynamics at Kiltartan so as to avoid any flow restrictions. The flow to be considered while designing the motorway was determined under this report and found to be approximately $100m^3/s$.

Review of the April 1998 South Galway Flood Study Engineering Proposals for an Overland Flood Overflow Channel between Coole Lough and Kinvarra

As part of the Review of the April 1998 South Galway Flood Study Reports, Jennings O'Donovan (JOD) carried out an assessment of the previously selected routes for an overland channel from Coole Lough to Caherglassaun Lough and ultimately to Kinvarra. Under this assessment, the route was refined based on site surveys carried out in November and December 2010, aerial photographs of the November 2009 flood and review of a report commissioned by the IFA Flood Committee completed by David Murray in September 2010. The construction of an overland flood overflow channel between Coole Lough and Caherglassaun Lough was found to involve the excavation of a 580m long channel 3m wide at the base and up to 1.25m deep. The continuation of this channel between Caherglassaun Lough and Kinvarra would involve a 5,150m long channel also 3m wide at the base and up to 7.5m deep.

While the construction of a channel between Coole and Caherglassaun was found to be acceptable in scale, the topography along the refined Caherglassaun to Kinvarra route is onerous to the construction of an engineered graded channel. Excavation depths of up to 7.5 metres would be required over the initial 1km to reach the Cahermore basin. Downstream from Cahermore, ground levels rise again and excavations of up to 5.5 metres would be required over a distance of approximately 2km. Such a channel would undoubtedly decrease the risk of

flooding. However, it would create a considerable scar to the landscape and could have a significant environmental and ecological impact.

Engineering Proposals for Restoration Works between Coole Lough and Kinvarra

As an alternative to constructing an overground flood overflow channel between Coole and Kinvarra, the possibility of locally improving drainage conditions was assessed under this study. This was carried out by identifying natural channel paths based on aerial photographs of the November 2009 floods and site surveys undertaken in November and December 2010. Two natural channels were identified.

The first natural channel between Coole and Caherglassaun crosses a number of boundaries such as hedges, fences and stone walls which caused hydraulic restrictions in November 2009. Six boundaries between fields were found to restrict flows and could feasibly be replaced by post and wire fences. Flood waters also crossed over the local road to Cahermore and there is currently no culvert crossing underneath this road.

The second natural channel between Caherawoneen and Kinvarra crosses 22 boundaries as well as a number of roads, the N67 road to Kilcolgan ; the R347 road to Adrahan ; and two local roads. Culvert replacement has already taken place at the downstream end on the N67 (twin arches 1.0m high by 2.0m wide each) and on the R347 (twin arches 1.0m high by 2.0m wide each) following a recommendation made in the 1998 South Galway Flood Study Report. Culverts to match the capacity of the twin arches could feasibly be constructed on the two remaining local road crossings and post and wire fences could feasibly be constructed at the 22 boundary crossings.

Overground Condition Survey of Key Swallow Holes

During the November 2009 flood, the capacity of the underground system was significantly decreased and flood waters found their way overground as the key swallow holes were clearly not capable of conveying flood flows underground. An overground condition survey of key swallow holes was carried out by JOD in December 2010 and completed in January 2011. Generally, it was found that the area surrounding a typical swallow hole is overgrown. Debris and pieces of wood washed away by the rivers usually end up floating in the water at the sink or on the embankments which could potentially block the entrance. The area in the immediate vicinity of a typical sink is not secure which could lead to animals and cattle falling or disturbing the ground.

More specifically, a very significant amount of waste was found floating at Polltoophil North sink (Castletown) which is located immediately downstream from Gort. Polltoophil South is currently partially blocked and shows significant weed growth on the banks of the channel leading to the sink.

At Caherglassaun, Pollnapasty sink shows overgrown vegetation and old stone walls around the sink which could fall and partially block the flow of water. Numerous plastic bags were observed on the embankments and the entrance of an active cave located approximately 150m to the north is currently blocked and needs attention.

At Kiltartan, Pollomuiri sink was found to be in acceptable condition. Clearing of its banks is however necessary as well as clearing of the upstream channel from Polldeelin spring as fallen trees in particular were identified. Secondary sinks in the area (known as Pollonora caves) also need attention.

COST ESTIMATES & COST BENEFIT ANALYSIS

A detailed breakdown of cost estimates for each scheme was prepared as part of this study. The cost estimate in relation to the possible Overland Flood Overflow Channel between Coole Lough and Kinvarra was revised from the original estimates carried out under the April 1998 South Galway Flood Study Report to reflect 2010 prices and refinements in the design. Cost estimates were subsequently assessed from a cost benefit point of view based on the Minor Works Funding Framework. The results are as follows :

	Engineering Proposals	Capital Costs (excludes VAT)	Benefit
1.	Restoration Works at Kiltartan	€341,125.00	POSITIVE
2.	Possible Overland Flood Overflow Channel between Coole Lough and Kinvarra	€48,230,759	NEGATIVE
3.	Restoration Works between Coole Lough and Kinvarra	€248,250.00	POSITIVE

As can be seen above, benefits were found to be positive for Restoration Works at Kiltartan and between Coole Lough and Kinvarra.

It is however not possible to justify the construction of an Overland Flood Overflow Channel between Coole Lough and Kinvarra at an estimated cost of €48,230,759 excluding VAT in a cost benefit analysis. This was found to be consistent with the conclusions of the April 1998 South Galway Flood Study Report.

CONCLUSION & RECOMMENDATIONS

The following are the conclusions and recommendations of the report on completion of the assessment of the engineering proposals and the outcome of the cost benefit analysis.

Restoration Works at Kiltartan

- Provision of culverts at Kiltartan :
  - Reconstruction of the existing culvert crossing under the N18, culvert to be 3.0 metres wide by 2.0 metres high
  - Construction of a culvert to cross under the local Kiltartan to Raheen road, culvert to be 3.5 metres wide by 1.5 metres high
  - Clearing of the existing arch bridge under the local Kiltartan to Raheen road. Ground levels in and out of the structure to be regraded / levelled to improve hydraulic smoothness
  - Regrading of agricultural access road and lands in its immediate vicinity along the Corker overflow

- M18 related works – it is considered absolutely essential that the design of the new motorway include the following :
  - Protection of the natural underground conduits while constructing the road
  - Design in a manner that no settlement will take place over the years to prevent the collapse of the underground conduits
  - Provide a 100 m^3/s culvert where the M18 crosses the Corker overflow to avoid any flow restrictions

- Cleaning works at Kiltartan :
  - It is recommended that cleaning works at Kiltartan be carried out at the entrance of the following karstic features :
    - Pollnacapall rise (receives flows from the Ballylee sink),

- Polldeelin rise (receives flows from the Castletown sink),
- Pollomuiri sink (main swallow hole under Coole Ridge to Coole turlough),
- Pollonora sinks which consist of a number of smaller but significant swallow holes under Coole Ridge to Coole turlough. There are at least four Pollonora sinks including one along the route of the Corker overflow.

▪ It is also recomended to carry out cleaning works in relation to the following items :
- River bed and banks (1km approx in length in the Kiltartan area)
- Surrounding lands generally should be cleared from debris

Overland Flood Overflow Channel between Coole Lough and Kinvarra

The following possible works, which are technically feasible, could not be justified in a cost benefit analysis and are unlikely to meet with approval on ecological examination :

o Coole to Caherglassaun overground flood overflow channel :
▪ 3.0 metres wide (at the base) open channel 0.75m to 1.25m in depth and approximately 580 metres in length – side slopes @ 3/2

o Caherglassaun to Kinvarra overground flood overflow channel
▪ 3.0 metres wide (at the base) open channel up to 7.5 metres in depth and approximately 6,600 metres in length – side slopes @ 3/2 – top width up to 25 metres

Restoration Works between Coole Lough and Kinvarra

A range of measures were identified between Coole Lough and Kinvarra for the purpose of restoring natural channel paths and locally improve drainage conditions :

o Restoration Works between Coole Lough and Caherglassaun Lough :
▪ Replace six boundary crossings such as stone walls and hedges by concrete post and wire fences to decrease flow restrictions along the natural channel path
▪ Construction of a culvert to cross under the local road to Cahermore, culvert to be 3.5 metres wide by 1.5 metres high

o Restoration Works between Caherawoneen and Kinvarra :
▪ Replace 22 No. boundary crossings such as stone walls and hedges by concrete post and wire fences to decrease flow restrictions along the natural channel path
▪ Construction of two culverts at two separate locations between Caherawoneen and Kinvarra to cross under local roads, each culvert to be 3.5 metres wide by 1.5 metres high

General condition survey of key Swallow Holes – Blackrock to Kinvarra Area

The area surrounding a typical swallow hole is generally overgrown. Debris and pieces of wood washed away by the rivers usually end up floating in the water at the sink or on the embankments. It is recommended that the area surrounding swallow holes be cleared from debris to prevent potential blockages. Consideration should also be given to fencing off the area around each of the karstic features using post and wire fencing to prevent cattle / animals from falling and disturbing the ground. Fencing off should be discussed with landowners.

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1. INTRODUCTION & BACKGROUND / HISTORICAL FLOODING EVENTS

1.1 INTRODUCTION

Jennings O'Donovan & Partners (JOD) were appointed in July 2010 by the Office of Public Works (OPW) as Consulting Engineers to Review the recommendations of the South Galway Flood Study Report dated April 1998. Included in the brief was the development of engineering proposals for the reinstatement of culverts on the N18 at Kiltartan and the provision of new culverts on the existing adjacent minor county Kiltartan to Raheen Road. This is the subject of this report which also addresses the feasibility of an overland channel from Coole to Kinvarra.

1.2 SCOPE OF WORKS

This report focuses on Items 1.4 and 1.3.3 of the Scope of Works. Under Item 1.4, JOD are required to develop Engineering Proposals for the reinstatement of culverts on the N18 at Kiltartan and for the provision of new culverts on the existing minor county road between Kiltartan and Raheen. The specific requirements for JOD as outlined in Item 1.4 of the scope of works are as follows :

- "Site Inspection, assessment of existing roads and general surrounding topography, selection & confirmation of existing culvert locations.
- Sizing of new culverts.
- Review of proposal to reinstate a natural overflow channel for Kiltartan (Corker overflow).
- Review proposal for water transfer across new N18.
- Hydrological analysis and informed assessment of hydrological impact of culvert proposal on overground route and on water levels at Coole.
- Preparation of cost estimate for restoration works.
- Preparation of report and recommendations for engineering restoration works with outline drawings as necessary to support any engineering works proposed.
- Identification of environmental constraints, if any."

Under Item 1.3.3, JOD are required to confirm no overarching constraints exist on, and prepare an updated cost estimate for, the proposed open channel from Caherglassaun to Kinvarra.

In addition, in this report, JOD assesses the conditions of the existing River system in Kiltartan and proposes a range of reinstatement works in order to restore natural flow conditions. This report also assesses the transfer of water downstream from the Kiltartan area and particularly, the feasibility of an overland flood overflow channel from Coole Lough to Caherglassaun Lough and from Caherglassaun to Kinvarra.

1.3 BACKGROUND / 2009 FLOODING EVENT[1]

In November 2009 and particularly the first three weeks of the month, a number of weather events occurred which resulted in record rainfall and high water levels being recorded in many parts of County Galway. The flooding at Kiltartan was as a result of several days of persistent rain over the county combined with high winter water tables. This resulted in water levels which significantly exceeded those normally encountered during the same period.

At NUI Galway, the station recorded a monthly total of 329.4mm of rain in November 2009, which represents 286% of the average November rainfall for the period between 1961 and 1990. Leading up to this flooding, a peak daily rainfall of 60.8mm was recorded at NUI Galway on the 17th November 2009.

Further data sourced from the Met Eireann Report on the November 2009 rainfall is shown on Table 1.1 overleaf.

[1] Rainfall data & return periods in this Section were souorced from the Met Eireann Report on the November 2009 floods

(Return Period in Years[2])	2 Day Totals		4 Day Totals		8 Day Totals		16 Day Totals		25 Day Totals	
Weather Station	**Rain mm**	**Ret Period**	**Rain mm**	**Ret Period**	**Rain mm**	**Ret Period**	**Rain mm**	**Ret Period**	**Rain mm**	**Ret Period**
CLOOSH	87	9	139	45	184	50	269	75	344	70
BALLINASLOE	63	20	99	**159**	153	**>500**	225	**>500**	271	**>500**
ROUNDSTONE	66	4	101	11	147	19	251	**110**	348	**280**
GALWAY (NUI)	90	**134**	127	**293**	175	**306**	255	**272**	316	**131**
MAAM VALLEY	61	1	99	1	194	1	301	1	432	1
BALLYGAR	77	73	110	**201**	157	**405**	228	**>500**	267	**251**
GORT	93	45	125	69	205	**443**	301	**>500**	413	**>500**

Table 1.1 : November 2009 rainfall recorded in County Galway – Source Met Eireann

The heavy rainfall in November 2009 was followed by peak flood levels at Kiltartan as illustrated in the photographs below :

Figure 1.1 : Flood Waters crossing over the N18 & Railway crossing at Kiltartan November 2009 Floods

Figure 1.2 : Kiltartan Aerial Photograph November 2009 Floods

[2] Rainfall return periods above 100 years are shown red

As can be seen in Figure 1.1, waters flooded the N18 at Kiltartan as well as a significant section of the adjacent Limerick to Galway railway. The church at Kiltartan was flooded and a number of houses became isolated and surrounded by flood waters. 2 to 3 feet of water which is equivalent to 0.6m to 0.9m, were reported on the local road from Kiltartan to Raheen :

Figure 1.3 : Kiltartan to Raheen local Road – Flood level 14.5 to 15.0mOD approximately November 2009 Floods

Figure 1.4 : Kiltartan church (FFL @ 14.25mOD) – Flood level 14.5m to 15.0mOD approximately November 2009 Floods

The mechanisms that lead to the extreme November 2009 flooding event are further described in Section 2.

2. DATA AVAILABLE AND METHODOLOGY USED

2.1 COLLECTION OF DATA

Information on historic flood events within the Kiltartan Area was sourced from the OPW National Flood Hazard Mapping website (www.floodmaps.ie) as well as from the following studies and surveys :

- An Investigation of the Flooding Problems in the Gort – Ardrahan Area of South Galway – April 1998 Final Report for the Office Of Public Works – Jennings O'Donovan & Partners / Southern Water Global
- A Report on the Flooding in the Gort – Ardrahan Area – January 1992 – Geological Survey of Ireland
- Flooding Analysis – Kiltartan to Kinvarra : November 2009 – David Murray / IFA Flood Committee
- Flooding at Kiltartan – November 2009 – David Murray
- Report on Flooding in South Galway in 1994 – May 1994 – OPW
- Report on the November 2009 rainfall in Ireland – Met Eireann website (www.met.ie)

Aerial photographs of the November 2009 flood as well as the mid and late 1990s floods in the study area were provided by the OPW.

The layout of the future M18 motorway between Gort and Tuam was also considered. The layout is shown on the drawings appended.

2.2 JOD SURVEY – AUGUST 2010

In addition to the data collected from previous studies and surveys as outlined above, JOD carried out a detailed topographical survey of the Kiltartan Area using a GPS ProMark 500. The survey was carried out between the 23rd of August 2010 and the 27th of August 2010. The following was recorded :

- **River Bed levels,**
- **Left and right banks levels,**
- **N18 Road levels,**
- **Kiltartan to Raheen local Road level,**
- **Surrounding lands levels,**
- **Culverts geometry,**
- **Condition of the channels (blockages, structural restrictions and over grown areas).**

The above data was subsequently processed and the size of existing culverts assessed in terms of structural condition and hydraulic capacity.

2.3 METHODOLOGY FOR ASSESSING EXISTING CULVERTS

In order to appropriately assess the size of existing culverts, it is a requirement to estimate the hydraulic flow which can be expected in the Kiltartan area. Flows are traditionally estimated by carrying out a desktop study and by comparing / validating the results of the desktop calculations with :

1. The actual flows recorded in the past on various gauging stations throughout the catchment,
2. The detailed assessment of old hydraulic structures that are locally known to be good indicators of natural flow conditions.

The dynamics of the Slieve Aughty catchment are however significantly different than most river catchments encountered in Ireland and any hydrological modelling attempt requires particular care. In relation to Kiltartan, the surrounding land surface is low lying and relatively flat, with elevations ranging from sea level at Kinvarra (downstream) to 30 mOD in Gort (upstream). The area is bounded by the coastline at Kinvarra. The boundary to the east is with the poor aquifer lithologies. To the north and south, surface water divides act as the boundaries, which includes the catchment divide between the Shannon and the

Western Basin areas. Karstification is widespread, with 273 features recorded. Many swallow holes / sink holes can be seen at various location within the catchment where overground rivers are swallowed through large conduits, fissures, faults, joints and bedding planes. Most groundwater flows in an epikarstic layer 1 to 10 metres deep and in a zone of interconnected enlarged fissures and conduits that extends approximately 30 metres below the epikarstic layer. The major conduits such as Polldeelin are up to 20 metres in diameter. Deeper inflows can occur in areas associated with faults or dolomitisation. Deep groundwater flow was encountered at 77 metres below ground level at Loughcurra South, 2 km southeast of Kinvarra. The Slieve Augthy catchment is therefore unique and particular attention should be given to any attempt to model the dynamics of the waters. A model of the catchment was originally built as part of the South Galway Flood Study (1998). This model has been subsequently developed by a team lead by Mr. Paul Johnston, Trinity College Dublin (TCD), who have input additional data collected throughout the years (dynamics of turlough levels, rainfall data and flows). This model continues to be enriched by TCD to further develop the understanding of the Slieve Aughty catchment.

As opposed to the TCD model, the construction of a traditional model is deemed to be not suitable for such a catchment. However, it was found that locally, and for the purpose of estimating extreme flood flows for culvert sizing, traditional methods can be used as the dynamics of the catchment change significantly under flooding conditions. During the November 2009 flood, the capacity of the underground conduits was reduced and a significant amount of water found its way overground as the head differential between the main swallow hole at Kiltartan and Coole Lough was gradually reduced to less than 2.5 metres. In Kiltartan, it is understood that flooding was caused by the following sequence of events :

1. Flow capacity of the underground system downstream was exceeded (Coole Lough to Caherglassaun Lough to Kinvarra cave system)
2. Water levels rose significantly at Caherglassaun Lough and then at Coole Lough

3. The head differential between Coole Lough and the main sink hole at Kiltartan (known as Pollomuiri) decreased significantly which subsequently reduced the capacity of the underground system from Kiltartan to Coole
4. Water levels rose at Kiltartan and water found its way through a natural winter "overflow" channel at Corker.

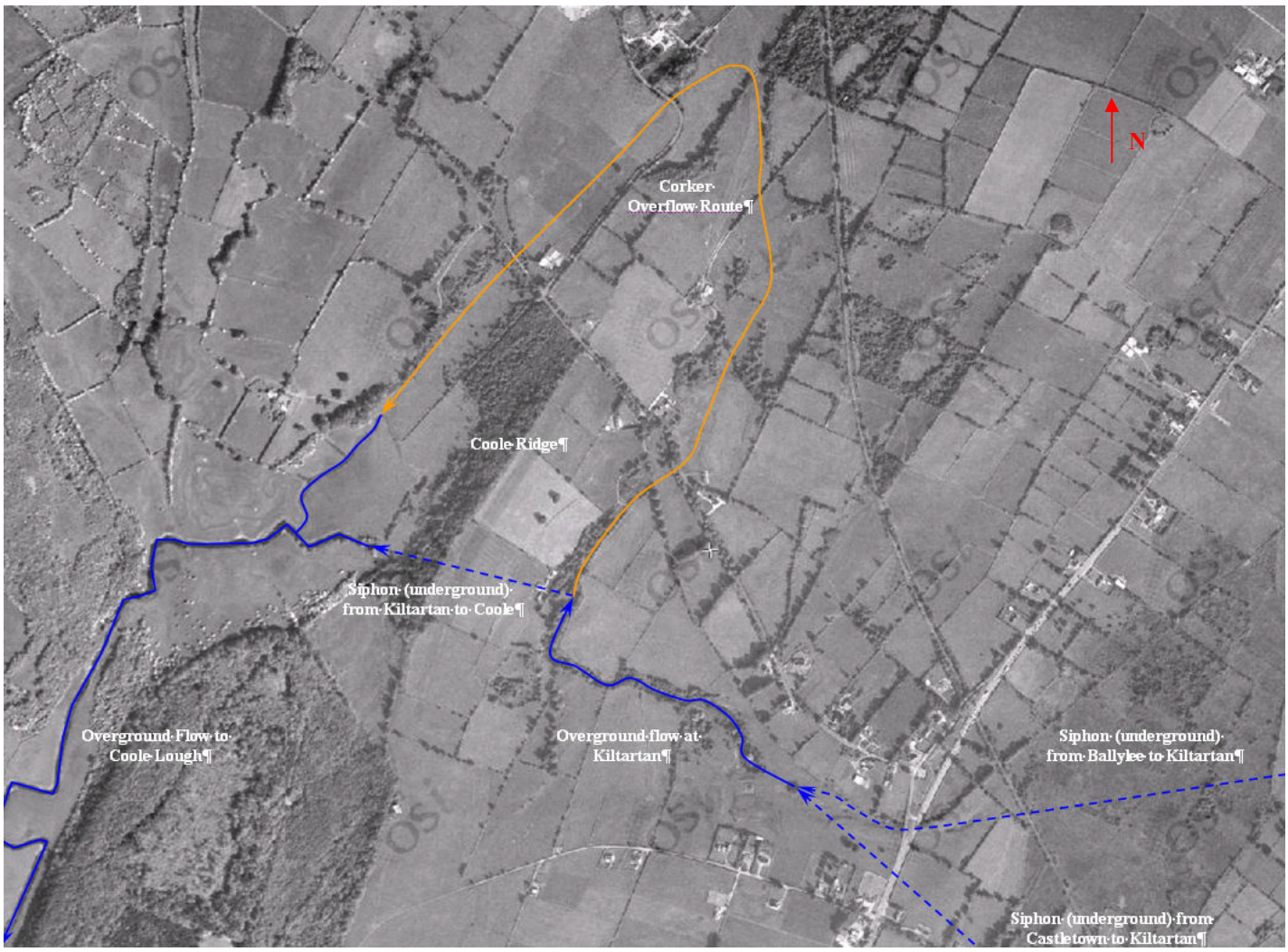

Figure 2.1 : Kiltartan schematic

During the November 2009 floods, underground systems gradually decreased in flow capacity in response to reduced head differentials. Flood waters tended to flow overground as illustrated in the following aerial photos :

Figure 2.2 : Corker overflow November 2009 Floods

Figure 2.3 : Corker overflow November 2009 Floods

As a significant proportion of the flow is over ground under extreme flooding conditions, it is deemed satisfactory to generate design flows using traditional methods, for the purpose of culvert sizing only in the Kiltartan area.

This was further confirmed under a separate study carried out in 2009 / 2010 on the Dunkellin catchment, east of Kilcolgan. Under normal flow conditions, a significant proportion of the Dunkellin river is known to flow underground at Rahasane turlough. Under this study however, traditional "overground" modelling software was used and was successfully validated using flood levels and flows recorded during the November 2009 floods.

3. ESTIMATION OF THE DESIGN FLOWS FOR CULVERTS SIZING AT KILTARTAN

The following is an outline of the hydrological calculations, methods used, and assumptions made.

3.1 INTRODUCTION

As described under Section 2, the estimation of peak flows on the river system at Kiltartan using traditional overground calculation methods can be carried out for extreme flood events. The flows generated using these traditional methods are indicative only and have only been used for the purpose of confirming the sizing of culverts proposed under this report. As a number of hydrometric stations are available upstream from the Kiltartan area, design flows have been compared with actual flows recorded during the November 2009 flood in order to confirm the accuracy of the data generated from traditional calculation methods.

The flow values have first been estimated using the following three steps:

1. Slieve Aughty Catchment Analysis (three different methods are used),
2. Calculation of the preliminary flow values using the appropriate regional growth factors (XT) recommended for Ireland in the Flood Studies Report (NERC, 1975),
3. Application of appropriate factors for standard error and for the possible future climate change to the preliminary flow values estimated in (2) to calculate the actual design flow values.

The flow generated from the catchment analysis as described above was subsequently compared with the flow capacity of the old arch bridge located on the Kiltartan to Raheen local road.

3.2 ESTIMATION OF THE OVERGROUND FLOW BY CATCHMENT ANALYSIS

3.2.1 Preliminary Results

The estimation of the flows was carried out by a detailed assessment of the contributing catchment. The following methods were used :

- Method No.1 : Flood Study Report, 1975 – 6 Variable Equation
- Method No.2 : Flood Studies Institute Of Hydrology Report No.124, 1994 (IH124)
- Method No.3 : Crupedix Method (Department Of Agriculture – France)

A detailed calculation note is available as Appendix C.
The following table summarises the results obtained using the above methods :

Method No.	**1**	**2**	**3**
Preliminary design flow value (m3/s)	76.0	83.5	83.9

Table 3.1 : Summary of the preliminary design flow value

The greatest value of 83.9 m3/s will be taken into account for the purpose of this report.

3.2.2 Comparison With Flows Recorded In November 2009

There is a gauging station located in Lough Cutra which covers a subcatchment area of 123.8 km^2 or approximately 45% of the Slieve Aughty catchment. Water levels and flows are recorded on a daily basis. On the 20th of November 2009, the flow recorded at the station was 20.8 m3/s which is the average for the 24 hours period. As an indication, the maximum instantaneous flow on that particular day could be up to 100% above the average of 20.8 m3/s which would equate to 42 m3/s.

As this represents only 45% of the Slieve Aughty catchment, the peak flow to Kiltartan could have reached approximately 90 m3/s which is consistent with the figure of 83.9 m3/s given in Section 3.2.1.

3.2.3 Overground / underground flow split

Even under reduced head differential between Kiltartan and Coole, a proportion of this total flow of 83.9 m3/s will be conveyed underground. Groundwater velocities are estimated to be at least 150m/h in the area and can reach up to 1,000 m/h based on the information provided by the Kinvarra / Gort Summary of Characterisation (Geological Survey of Ireland). Based on this information and for the purpose of this report, it is estimated that 35% of the flow or 35% x 83.9 m3/s as a minimum will be conveyed underground.

The Preliminary Overground Flow is therefore taken to be 65% x 83.9 m3/s which equates to **54.5 m3/s**.

3.2.4 Recommended Factor For Standard Error & « Climate Change »

The regional growth curve method recommended by FSR (Flood Study Report – 1975) in Ireland has a standard factorial error of 1.5. This means that for two-thirds of catchments the percentage error would fall between +50% and -33%, and that in 1 in 20 cases they would overestimate flows by more than 120% or underestimate by more than 50%. (source : "Flood Estimation following the Flood Studies Report", Cunnane & Lynn, 1975). A Design Factor for standard error of 1.5 was therefore applied to the results.

A further factor of 1.2 was applied to the same results ("Climate change" factor).

Based on these factors, the Overground Flow is taken to be 54.5 m3/s x 1.5 x 1.2 which equates to 98 m3/s, rounded up to 100 m3/s.

3.3 COMPARISON WITH EXISTING ARCH BRIDGE FLOW CAPACITY AT CORKER (DOWNSTREAM)

There is an old arch bridge located on the Kiltartan to Raheen road on the route of the Corker overflow channel as shown in the Drawings appended.

Photo No.14 – Looking downstream to the arch bridge on the Corker overflow route
Refer to Drawing No. 4721/K/02 for the exact location

Photo No.14 above shows that the bridge is partially filled with debris accumulated over the years. A number of boulders are also currently blocking the downstream end of the bridge. Cleared from any debris, the bridge is approximately 1.5m high by 2.0m wide which gives a maximum wetted area of approximately 2.35 m^2. It is estimated that under gravity conditions, the flow transfer capacity through this bridge is approximately 30 m3/s. In November 2009, the bridge was surcharged as water reached the level of the Kiltartan to Raheen Road.

This means that flows in November 2009 along the Corker overflow (at the downstream end) could have been higher than 30 m3/s going through the bridge and even higher overall as a significant proportion of the water bypassed the bridge and flowed over the Kiltartan to Raheen Road as shown in Figure 3.1 below.

Figure No.3.1 – Corker overflow – Water flowing over the Kiltartan to Raheen Road Road levels at this location 12.90mOD – Flood levels estimated to be 13.0 to 13.5mOD approx.

November 2009 Floods

3.4 CONCLUSION

The flows generated in this report for the purpose of culvert sizing are as follows :

- Flow No.1 : 100 m3/s which is the estimated overground flow generated by the catchment, found to be consistent with last November 2009 flows
- Flow No.2 : 30 m3/s which is the estimated overground flow derived from a detailed assessment of the existing arch bridge on the Corker overflow

It is proposed under this report to consider Flow No.2, 30 m^3/s, to assess the suitability of existing culverts on the overground flow route at Kiltartan as this flow matches the capacity of the existing arch bridge and therefore reflects natural flow conditions in the area. For any new culverts such as the culvert to be considered under the M18, it is proposed to consider Flow No. 1, 100 m^3/s.

4. ENGINEERING PROPOSALS FOR RESTORATION WORKS AT KILTARTAN

4.1 INTRODUCTION

Flooding in November 2009 was due to record rainfall and high water levels being recorded in many parts of County Galway. Significant flow restrictions downstream from the Kiltartan area ; between Coole Lough and Caherglassaun Lough ; and between Caherglassaun and Kinvarra were identified and as a result water levels rose upstream at Kiltartan to reach previously unrecorded levels at the N18 road crossing. The proposals for restoration works at Kiltartan will have a positive impact locally (i.e. east of the Coole Ridge at Kiltartan) and it is recommended that similar measures be taken downstream to improve the overall drainage issues, (i.e. west of the Coole Ridge or South West of the local Kiltartan to Raheen Road up to Kinvarra).

4.2 ECOLOGICAL & ENVIRONMENTAL CONSIDERATIONS

It should be noted that some of the works proposed in this Section No.4 require further assessment in terms of their environmental impacts as a number of Designated Areas (Special Areas of Conservation (SAC), Special Protection Areas (SPA) and proposed Natural Heritage Areas(pNHA)) are located downstream from Kiltartan as shown on Drawing No. 4721/K/06 appended :

- **Coole Lough and surrounding lands :** **SAC, SPA & pNHA**
- **Caherglassaun Lough and surrounding lands :** **SAC & pNHA**
- **Kinvarra Bay :** **SAC, SPA & pNHA**

A separate study was commissioned in December 2010 by the Office of Public Works and is currently being carried out to specifically assess potential environmental impacts.

4.3 REINSTATEMENT OF CULVERTS AT KILTARTAN

4.3.1 Culvert across the N18

During the November 2009 floods, it became apparent that the existing culvert underneath the N18 road at Kiltartan was blocked and consequently flood waters rose above the level of the N18. As a result, the N18 was closed for a number of days as well as the adjacent Limerick to Galway railway. It is estimated that water levels above the N18 reached 18.2mOD.

Figure No.4.1 – N18 at Kiltartan November 2009 floods

Figure No.4.2 – N18 at Kiltartan November 2009 floods

As part of emergency works in November 2009, the old stone culvert crossing the N18 was identified.

Figure No.4.3 – N18 at Kiltartan
Emergency Works
November 2009 floods

Figure No.4.4 – N18 at Kiltartan
Partially unblocked culvert
August 2010

As can be seen in Figure No. 4.4, the culvert is still partially blocked. From detailed observations and measurements of the accessible part of the culvert, the size of the culvert can be estimated to be approximately 2.5 metres in width at the base and 1.5 metres high. A culvert of these dimensions is capable of conveying a capacity of 20 m^3/s. However, this is less than the $30m^3/s$ identified in Section 3.4 which is the estimated overground flow of the existing arch bridge on the Corker overflow. In addition, the culvert is in poor structural condition and may have sustained further damage from the flow of flood waters in November 2009.

It is therefore proposed to construct a new pre cast concrete culvert under the N18 to replace the existing old culvert which is under capacity and in poor structural condition. It is proposed that the pre cast concrete culvert be 3m wide and 2.0m high with associated pre cast splayed wing walls at the upstream and downstream ends.

Calculations were carried out using the following Manning-Strickler formula to assess the capacity of the proposed 3m wide by 2.0m high culvert as follows :

$$Q_{\max} = K \times S_w \times R_h^{2/3} \times \sqrt{S}$$

$$R_h = \frac{S_w}{P_w}$$

Where :

Q_{max} = Maximum Flow running through the culvert in m^3/s

K = Roughness Coefficient

S = Slope (m/m)

S_w = Wetted surface at capacity (m^2)

P_w = Wetted perimeter at capacity (m)

Numeric values are as follows :

Variable		Value	Source
Q_{max}	Maximum Flow (m^3/s)	31	
K	Roughness Coefficient (concrete structures)	67	Manning Strickler Parameter – Coefficient for Concrete Structure
S	Slope (mm/m)	7.5	
S_w	Wetted surface at capacity (m^2)	6.0	Manning Strickler Parameter
P_w	Wetted perimeter at capacity (m)	7.0	Manning Strickler Parameter

The maximum flow for a 3m wide culvert 2m high is 31 m^3/s, which is consistent the design flow of Q = 30 m^3/s.

The velocity of the water is as follows :

	Full capacity	10% of full capacity	1% of full capacity
Flow (m3/s)	31	3.1	0.31
Velocity (m/s)	5.2	2.7	1.1
Min. self cleansing velocities (m/s)	1	0.65	0.35

Self cleansing requirements were checked based on the above velocities and the size of the proposed culvert was found to be appropriate.

4.3.2 Culvert at the upstream end of Corker overflow on the local Kiltartan to Raheen Road

The local Kiltartan to Raheen road was raised following the 1995 flood event and 2 No. 150mm diameter pipes were placed as shown in Figure No. 4.5 below :

Figure No.4.5 – Upstream end of Corker overflow – 2 No. 150mm diameter pipes crossing the Kiltartan to Raheen road

Figure No.4.6 : Same location as adjacent Figure No.4.1

Flood waters flowing over the Kiltartan to Raheen road – November 2009 Floods

The existing twin 150mm concrete pipes are not adequate to transfer excess flows through Corker as is clearly evident from Figure 4.6.

It is proposed to construct a new pre cast concrete culvert to replace the existing 150mm dia. pipes which are significantly under capacity. It is proposed that the pre cast concrete culvert be 3.5m wide and 1.5m high with associated pre cast splayed wing walls at the upstream and downstream ends.

Numeric values are as follows :

Variable		Value	Source
Q_{max}	Maximum Flow (m^3/s)	30.5	
K	Roughness Coefficient (concrete structures)	67	Manning Strickler Parameter – Coefficient for Concrete Structure
S	Slope (mm/m)	10	
S_w	Wetted surface at capacity (m^2)	5.25	Manning Strickler Parameter
P_w	Wetted perimeter at capacity (m)	6.5	Manning Strickler Parameter

The maximum flow for a 3.5m wide culvert 1.5m high is 30.5 m^3/s, which is consistent with the design flow of Q = 30 m^3/s.

The velocity of the water is as follows :

	Full capacity	10% of full capacity	1% of full capacity
Flow (m3/s)	30.5	3.0	0.30
Velocity (m/s)	5.8	2.8	1.2
Min. self cleansing velocities (m/s)	1	0.65	0.35

Self cleansing requirements were checked based on the above velocities and the size of the proposed culvert was found to be appropriate.

4.3.3 Existing arch bridge at the downstream end of Corker overflow on the local Kiltartan to Raheen Road

The existing arch bridge located at the downstream end of the Corker overflow was found to be in good structural condition and capable of conveying approximately 30 m3/s at full capacity under gravity conditions. It is therefore recommended that this culvert be retained and that existing boulders located at both entries be cleared. Any debris in the area should also be cleared so as to avoid any flow restrictions. It is also recommended that ground levels in and out of the structure be regraded / levelled out in order to decrease friction losses and improve hydraulic smoothness.

4.4 RESTORATION WORKS OF THE NATURAL OVERFLOW CHANNEL AT CORKER

It is recommended that a short section approximately 25m long be regraded along the natural Corker overflow channel as shown on Drawing 4721/K/05 available as Appendix A. Excavation works for the purpose of regrading are minor as they concern an existing agricultural access road which is above the 13.0 metres O.D. mark only. The width of the 25 metres section levelled out at 13.0mO.D. will be 2.0 metres maximum at the base with side slopes at 5/2 so as to tie in smoothly with adjacent lands.

4.5 CLEANING & MAINTENANCE WORKS

Maintenance works are recommended so that no debris accumulate over the years and so as to avoid any flow restrictions especially along the Corker overflow. It is also recommended to clean and maintain existing swallow holes as well as the bed and banks of the river in the Kiltartan area. Particular care should be taken of swallow holes as they could be significantly restricted in flow capacity by trees and debris washed away by floods. There are a number of swallow holes in the area :

- Pollnacapall rise (receives flows from the Ballylee sink),
- Polldeelin rise (receives flows from the Castletown sink),
- Pollomuiri sink (main swallow hole under Coole Ridge to Coole turlough),

- Pollonora sinks which consist of a number of smaller but significant swallow holes under Coole Ridge to Coole turlough. There are at least four Pollonora sinks including one along the route of the Corker overflow.

A general condition survey of key swallow holes in the area was carried out as part of this report and is presented under Section No.7.

Karstic features should be closely monitored and maintained so that the natural underground cave system remains unblocked. The benefits in maintaining these are significant and range from the conservation of a unique environment to the prevention of flooding.

5. REVIEW OF THE APRIL 1998 SOUTH GALWAY FLOOD STUDY ENGINEERING PROPOSALS FOR AN OVERGROUND FLOOD OVERFLOW CHANNEL BETWEEN COOLE LOUGH AND KINVARRA

5.1 INTRODUCTION

As part of the Review of the South Galway Flood Study Reports, JOD carried out an assessment of the previously selected routes for an overland channel from Coole Lough to Caherglassaun Lough and ultimately to Kinvarra. The assessment was aimed to identify any overarching constraints and to recommend preliminary improvement works.

It should be noted that a separate assessment of the Coole to Kinvarra area was carried out under Section No.6 to identify minor restoration works / local improvement works as opposed to the proposal for an overground flood overflow channel detailed under this Section No.5.

Preliminary design works proposed under this Section No.5 should be further investigated by carrying out a detailed topographical survey of the area. It is also recommended that hydrological modelling be carried out in order to quantify the effect of the possible works on flood levels and so as to avoid any negative impact.

5.2 ECOLOGICAL & ENVIRONMENTAL CONSIDERATIONS

It should be noted that some of the works proposed in this Section No.5 require further assessment in terms of their environmental impacts as a number of Designated Areas (Special Areas of Conservation (SAC), Special Protection Areas (SPA) and proposed Natural Heritage Areas(pNHA)) are located within and downstream from the Coole & Caherglassaun areas as shown on Drawing No. 4721/K/06 appended :

- **Coole Lough and surrounding lands :** **SAC, SPA & pNHA**
- **Caherglassaun Lough and surrounding lands :** **SAC & pNHA**
- **Kinvarra Bay :** **SAC, SPA & pNHA**

A separate study was commissioned in December 2010 by the Office of Public Works and is currently being carried out to specifically assess potential environmental impacts.

5.3 COOLE LOUGH TO CAHERGLASSAUN LOUGH CHANNEL

The previously selected route between Coole Lough and Caherglassaun Lough is shown on Drawing 4721/K/07 attached as Appendix A. This route was investigated under the South Galway Flood Study 1998 Final Report and further assessed following the November 2009 floods under a report commisioned by the IFA Flood Committee. The IFA Report, prepared by David Murray and finalised in September 2010, states that excess flood waters in November 2009 tended to overflow from Coole Lough to Caherglassaun Lough and to follow the route investigated by JOD / Southern Water Global in the South Galway Flood Study Report.

This natural overflow route from Coole to Caherglassaun is however restricted in its capacity to transfer flows particularly where it crosses the local road leading to Cahermore.

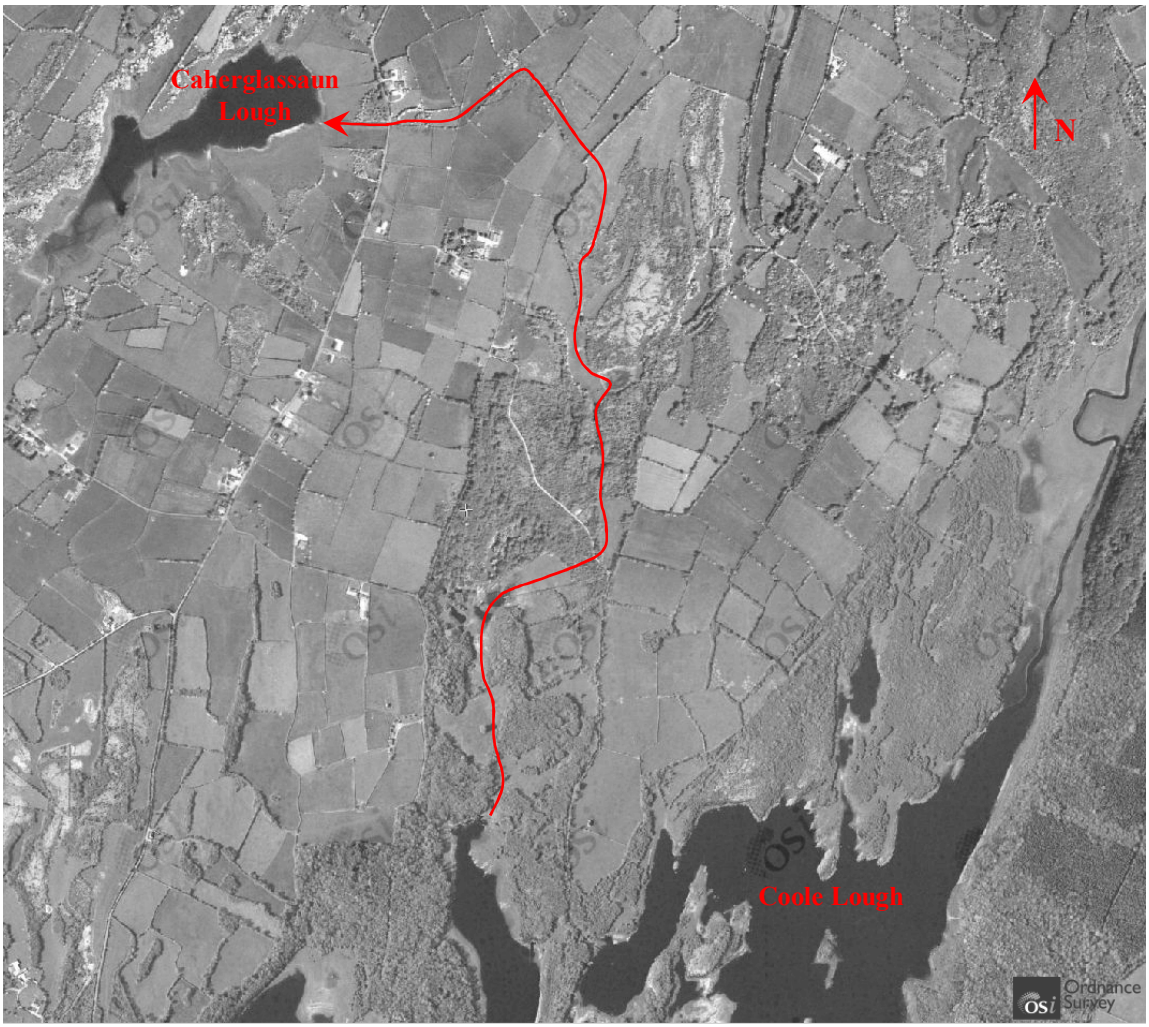

Figure No.5.1 – Coole to Caherglassaun natural overflow

As can be seen in Figure 5.1 above, the route of this natural overflow follows low lying areas in a north westerly direction. It is technically feasible to improve the capacity of this natural route as described in the 1998 South Galway Flood Study Report. This would involve minor excavation works to lower ground levels upstream from the road crossing (northern end of the alignment only) as well as the construction of a culvert under the road to Cahermore and an additional culvert under an agricultural access road as shown on Drawing No. 4721/K/07.

Preliminary Design Proposals are shown on Drawing No. 4721/K/07 and include :

- Construction of a 3 metres wide (at the base) open channel 0.75m to 1.25m in depth and approximately 580 metres in length – side slopes @ 3/2 to decrease maintenance requirements,
- Construction of a culvert to cross under the local road leading to Cahermore as shown on Drawing No. 4721/K/07. The culvert would be 3.5 metres wide and 1.5 metres deep with associated pre cast splayed wing walls at the upstream and downstream ends.
- Construction of a culvert to cross under the local agricultural access road as shown on Drawing No. 4721/K/07. The culvert would be 3.5 metres wide and 1.5 metres deep with associated pre cast splayed wing walls at the upstream and downstream ends.

It should be noted that this possible overground flood overflow channel between Coole and Caherglassaun will have an impact downstream at Caherglassaun and could increase the risk of flooding in the Caherglassaun area if measures are not matched downstream. Possible downstream works were also investigated under the April 1998 South Galway Flood Study Report and are presented under Section No.5.4 below.

5.4 CAHERGLASSAUN LOUGH TO KINVARRA CHANNEL VIA CAHERMORE & CAHERAWONEEN

The previously selected route between Caherglassaun Lough and Kinvarra is shown on Drawings 4721/K/08 and 4721/K/09 attached as Appendix A. This route was originally investigated as part of the 1998 South Galway Flood Study Report and at the time, it was deemed technically feasible to construct an overland flood overflow channel to the sea.

This route has been refined under this report based on aerial photos of the November 2009 floods and on a review of the Kiltartan to Kinvarra November 2009 Flooding Analysis Report commissioned by the IFA Flood Committee and prepared by David Murray in September 2010.

The upstream part of the possible overland flood overflow channel between Caherglassaun and Caherawoneen via Cahermore is set out in Figure 5.2 as follows :

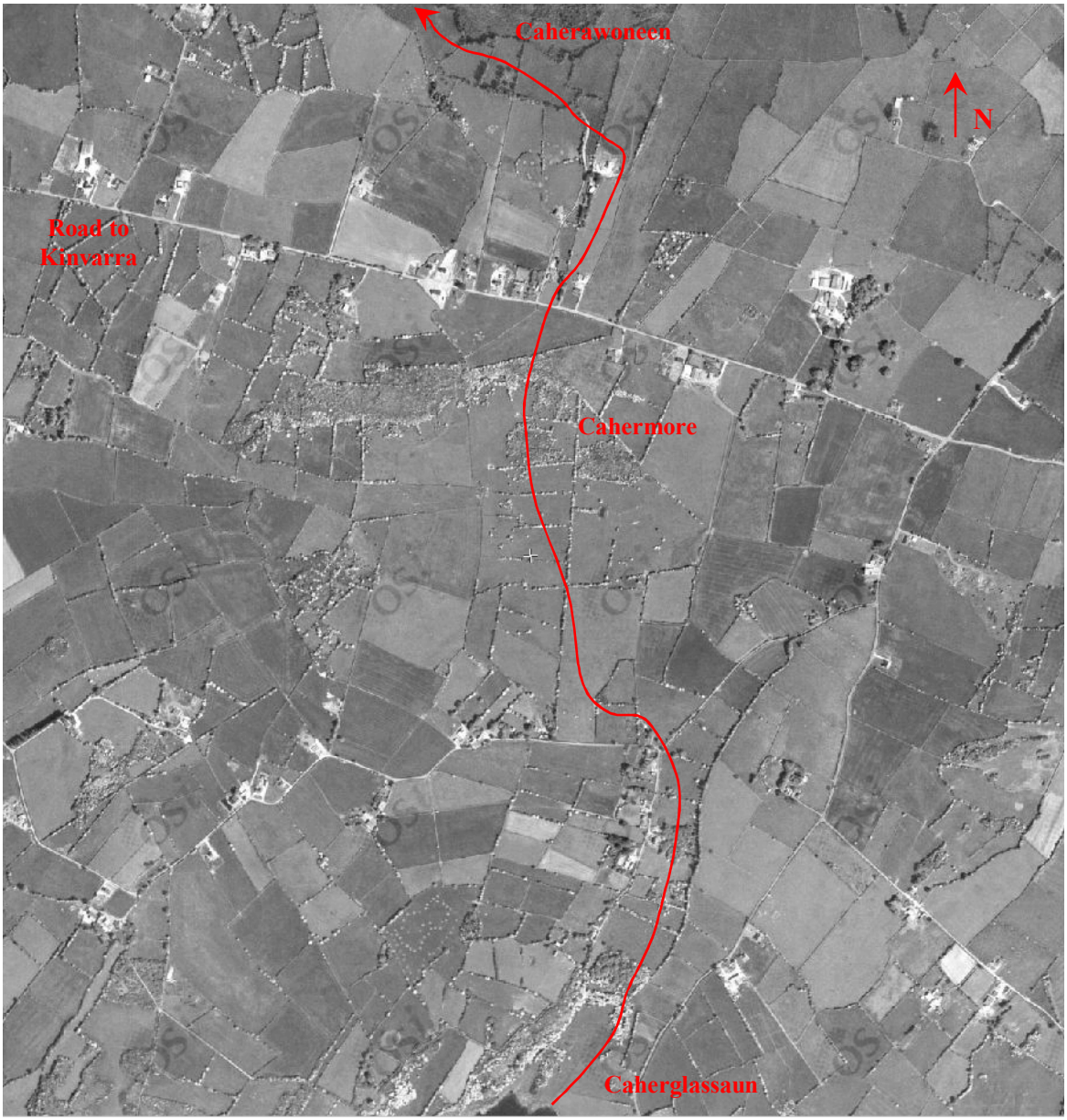

Figure No.5.2 – Possible Caherglassaun to Caherawoneen via Cahermore overland flood overflow channel

The route of the possible overland flood overflow channel downstream from Caherawoneen to Kinvarra is set out in Figure 5.3 as follows :

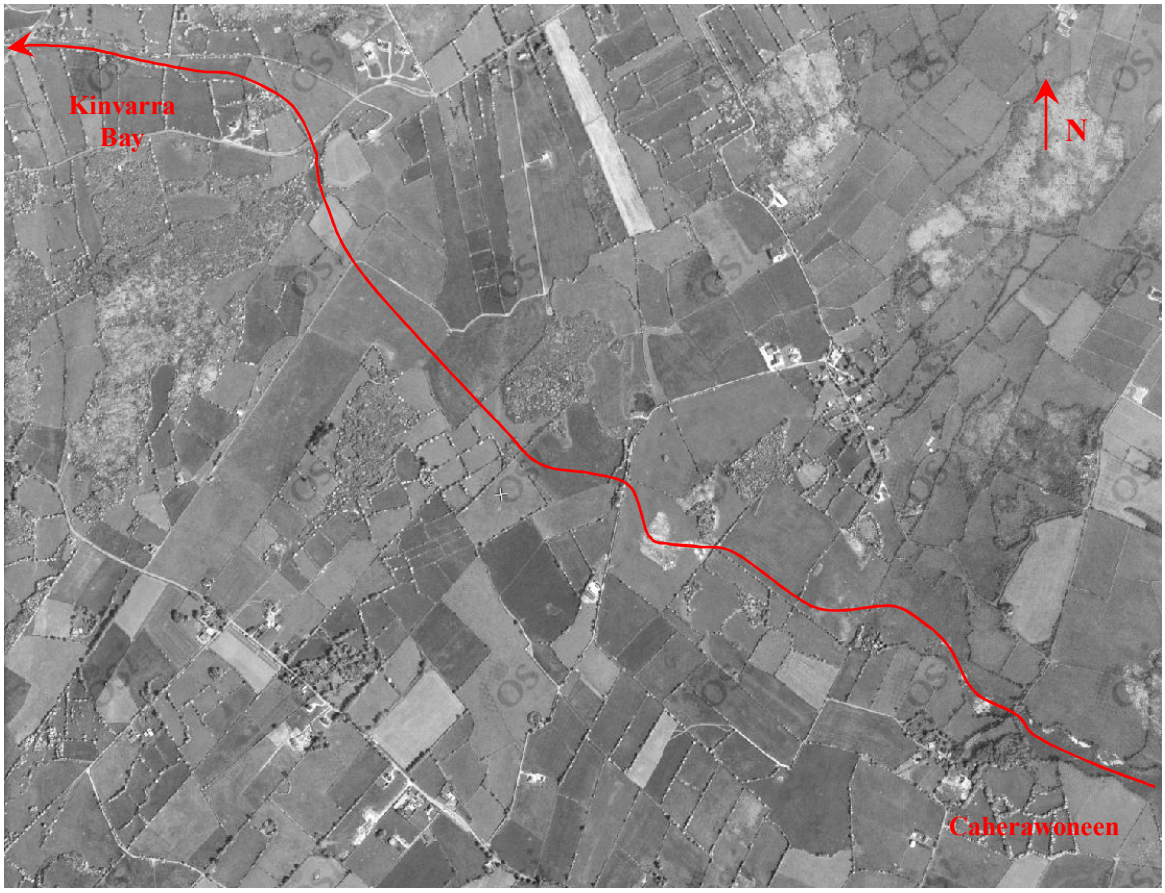

Figure No.5.3 – Possible Caherawoneen to Kinvarra overland flood overflow channel (continuation from Figure No.5.2)

As stated in the 1998 South Galway Flood Study Report, it is technically possible to construct an overland flood overflow channel between Coole and Kinvarra. The scale of the works however is significant especially between Caherglassaun and Kinvarra which would require excavations of up to 7.5 metres in depth as shown on Drawings 4721/K/08 and 4721/K/09 attached as Appendix A.

The main features of the Caherglassaun to Kinvarra possible channel are as follows :

- Length of the channel : 5,150 metres approximately
- Depth of the channel : up to 7.5 metres between Caherglassaun and Cahermore and up to 5.5 metres between Cahermore and Kinvarra
- Side slopes : 3/2
- Base width : 3.0 metres
- Top width : up to 25 metres in places due to the significant depths

The topography along the above possible refined route is onerous to the construction of an engineered graded channel. Excavation depths of up to 7.5 metres would be required over the initial 1km to reach the Cahermore basin. Downstream from Cahermore, ground levels rise again and excavations of up to 5.5 metres would be required over a distance of approximately 2km. Levels then gradually reduce over the final 1.5km and the scale of the construction works that would be required there are less significant. A number of culverts would have to be constructed where the possible channel crosses local roads between Caherglassaun and Kinvarra as shown on Drawings 4721/K/08 and 4721/K/09. Culvert replacement has already taken place at the downstream end on the N67 Kinvarra to Kilcolgan Road (twin arches 1.0m high by 2.0m wide each) and on the R347 Kinvarra to Adrahan Road (twin arches 1.0m high by 2.0m wide each) following a recommendation made on the 1998 South Galway Flood Study Report.

Such a channel would undoubtedly decrease the risk of flooding. However, it would create a considerable scar to the landscape and could have a significant environmental and ecological impact. The construction cost was estimated in the 1998 South Galway Flood Study Report as being IR£22,500,000 equivalent to €48,010,384 at 2010 prices. This did not represent value for money when subjected to a detailed cost benefit analysis as part of the 1998 South Galway Flood Study Report.

6. ENGINEERING PROPOSALS FOR RESTORATION WORKS BETWEEN COOLE AND KINVARRA

This Section No.6 sets out a range of local drainage improvement works between Coole Lough and Kinvarra for the purpose of restoring natural flow paths in the area.

It should be noted that, as opposed to the possible measures detailed under Section No.5, the drainage improvement works presented below will mitigate the impact of overland flood flows but will not protect against extreme flood events.

6.1 COOLE LOUGH TO CAHERGLASSAUN LOUGH – NATURAL CHANNEL PATH RESTORATION WORKS

Figures No.6.1 and 6.2 below show aerial photographs of the floods on the 30th of November 2009 in the Coole / Caherglassaun area :

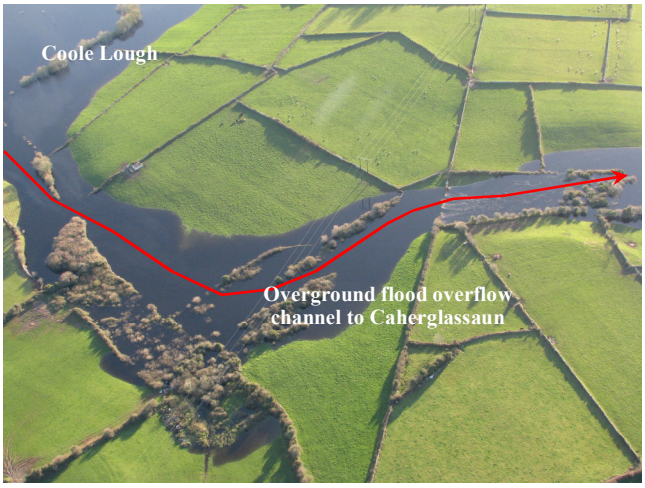

Figure No.6.1 – Overground Channel Path from Coole to Caherglassaun Upstream End

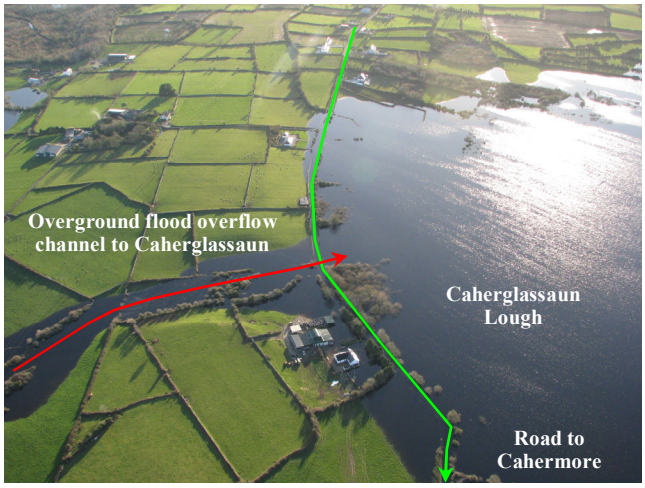

Figure No.6.2 – Overground Channel Path from Coole to Caherglassaun Downstream End

As can be seen above, excess water from Coole Lough overflowed to Caherglassaun Lough following the route detailed under Section No.5.3 – Figure 5.1. This natural channel

crosses a number of boundaries such as hedges, fences and stone walls which caused hydraulic restrictions. Flood waters also crossed over the road to Cahermore.

It is proposed to replace hedges, fences and stone walls by concrete posts and wire fences so as to decrease hydraulic restrictions. A survey was carried out on the 14th of December 2010 and six crossings were identified. The location of these crossings is shown on Drawing 4721/K/07 attached as Appendix A. It is also recommended to raise the local road to Cahermore by 200mm and to provide a culvert along the natural channel path. It is recommended that the proposed culvert be as follows:

- Precast concrete rectangular culvert 1.5m high by 3.5m wide including associated pre cast splayed wing walls at the upstream and downstream ends. Recommended levels for the new structure to be as follows :
  - Invert level of the proposed culvert : 10.20m OD Malin
  - Crown level of the proposed culvert : 11.70m OD Malin
  - Existing level of the road : 11.80m OD Malin
  - Proposed level of the road : 12.00m OD Malin
  - Depth to the crown of the culvert : 300mm – Class F Bedding

Ground levels in and out of the proposed culvert will have to be regraded / levelled out as part of the proposed works in order to decrease friction losses and improve hydraulic smoothness.

6.2 CAHERAWONEEN TO KINVARRA – NATURAL CHANNEL PATH RESTORATION WORKS

Figures No.6.3 and 6.4 below show aerial photographs of the floods on the 30th of November 2009 in the Caherawoneen / Kinvarra area (upstream side) :

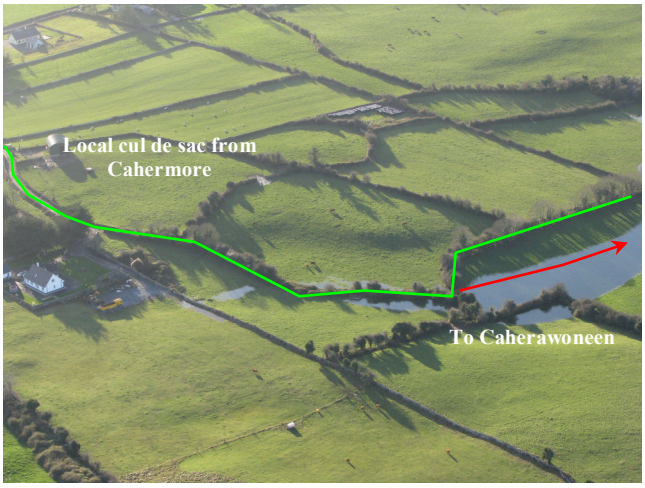

Figure No.6.3 – Overground Channel Path from Caherawoneen to Kinvarra Upstream Side (1 of 2)

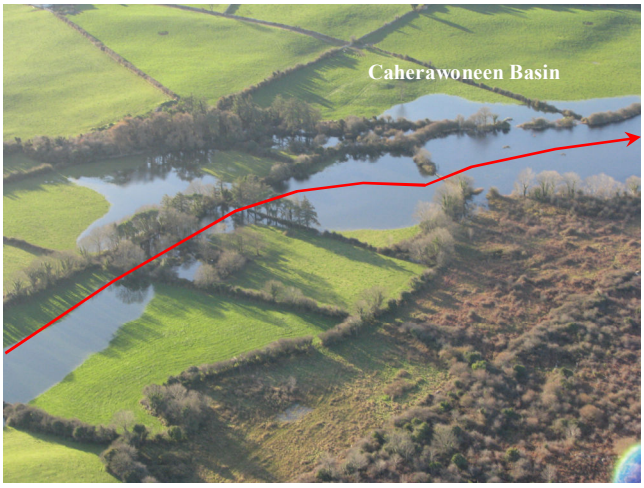

Figure No.6.4 – Overground Channel Path from Caherawoneen to Kinvarra Upstream Side (2 of 2)

Figures No.6.5 and 6.6 below show aerial photographs of the floods on the 30th of November 2009 in the Caherawoneen / Kinvarra area (downstream side) :

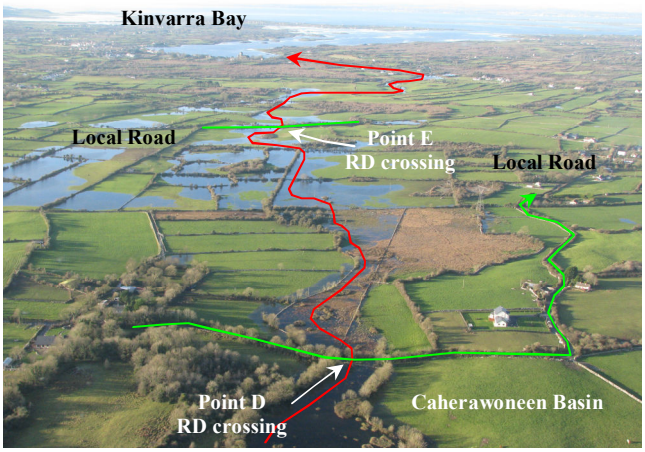

Figure No.6.5 – Overground Channel Path from Caherawoneen to Kinvarra Downstream Side (1 of 2)

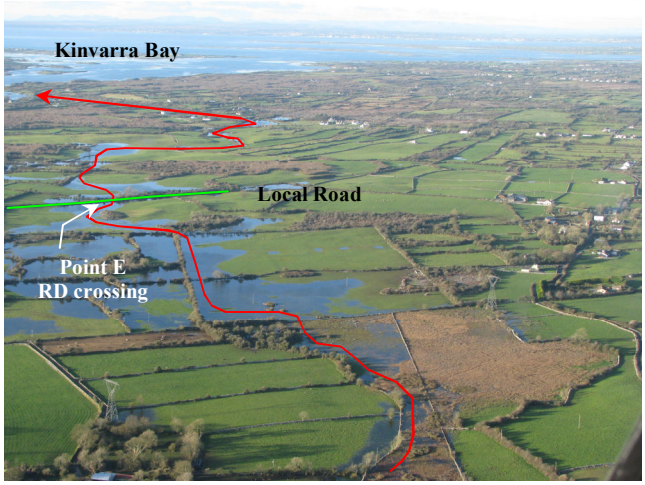

Figure No.6.6 – Overground Channel Path from Caherawoneen to Kinvarra Downstream Side (2 of 2)

As can be seen above, water from the Caherawoneen basin flowed to Kinvarra following the route detailed under Section No.5.4 – Figure 5.3. This natural path crosses a number of boundaries such as hedges, fences and stone walls which caused hydraulic restrictions. Flood waters also crossed over two local roads as shown on Drawing 4721/K/09 (Point D & Point E).

It is proposed to replace hedges, fences and stone walls by concrete posts and wire fences so as to decrease hydraulic restrictions. A survey was carried out on the 14th of December 2010 and 22 crossings were identified. The location of these crossings is shown on Drawing 4721/K/09. It is also recommended to raise the local roads at Point D and Point E by 200 to 400mm and to provide culverts to match the capacity the existing twin arches which are located further downstream on the N67 and R347 along the natural channel path. It is recommended that the proposed culverts be as follows :

- Point D : Twin arches 1.0m high by 2.0m wide or twin rectangular culverts 1.0m high by 1.75m wide including associated pre cast splayed wing walls at the upstream and downstream ends. Recommended levels for the new structure to be as follows :
  - Invert level of the proposed culverts : 9.80m OD Malin
  - Crown level of the proposed culverts : 10.80m OD Malin
  - Existing level of the road : 11.12m OD Malin
  - Proposed level of the road : 11.32m OD Malin
  - Depth to the crown of the culverts : 520mm – Class F Bedding

- Point E : Twin arches 1.0m high by 2.0m wide or twin rectangular culverts 1.0m high by 1.75m wide including associated pre cast splayed wing walls at the upstream and downstream ends. Recommended levels for the new structure to be as follows :
  - Invert level of the proposed culverts : 8.20m OD Malin
  - Crown level of the proposed culverts : 9.20m OD Malin
  - Existing level of the road : 9.10m OD Malin
  - Proposed level of the road : 9.50m OD Malin
  - Depth to the crown of the culverts : 300mm – Class F Bedding

Ground levels in and out of the proposed culverts will have to be regraded / levelled out as part of the proposed works in order to decrease friction losses and improve hydraulic smoothness.