Study to Identify Practical Measures to Address Flooding at Carnmore/ Cashla

August 2010

The Office of Public Works
Oifig na nOibreacha Poiblí

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue, Taylor's Hill, Galway
Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford Dublin 18

Client	**Office of Public Works**
Project No.	**2138//11/10**
Project Title	**Clare River Flood Study**
Report Title	**Study to Identify Practical Measures to Address Flooding at Carnmore/ Cashla**

Rev.	Status	Author(s)	Reviewed By	Approved By	Issue Date
0	Draft	J. Reid	C. Lyons	M. Joyce	September 2010
1	Final	R. Kiely	J. Reid	C. Lyons	26/11/10

TABLE OF CONTENTS

1. Introduction

1.1. Background

RYAN HANLEY was commissioned by the Office of Public Works (OPW) in March 2010 to carry out a study of the Clare River from Lough Corrib to Corofin and on the Abbert River from its outfall to the Clare River to Ballyglunin. A report entitled "Study to Identify Practical Measures to Address Flooding on the Clare River" was submitted to the OPW in June 2010.

RYAN HANLEY's appointment was subsequently extended to include an area in the townlands of Carnmore East & Cashla on the R339, Galway to Monivea Regional Road, which was affected by flooding over a two week period in November 2009. This report focuses on the flooding in the townlands of Carnmore East & Cashla, and should be read in conjunction with the "Study to Identify Practical Measures to Address Flooding on the Clare River" report.

The aim of the study is to identify practical measures to prevent or alleviate damage to dwelling houses and disruption to road users due to flooding in the townlands of Carnmore East & Cashla, for a flood of the magnitude of that experienced in November 2009. Local flooding of these townlands which followed the extreme rainfall events of October and November 2009 caused severe and prolonged hardship to residents and to commuters using the R339.

Flood alleviation measures are investigated in this report and their viability assessed, complete with outline designs and cost estimates.

1.2 Methodology

The study involved the following elements;

- Analysis of recent OPW topographical survey and aerial photography of the areas affected by flooding in November 2009.
- Topographical survey by Ryan Hanley of the flooded areas and proposed drainage routes including interviews with residents to establish the peak flood levels.
- Collection and examination of relevant meteorological data relating to the November 2009 flood and previous historical flood events (see also June 2010 report entitled "Study to Identify Practical Measures to Address Flooding on the Clare River")
- Hydrological analysis of collated meteorological data on historical flood events including the November 2009 flood (see also June 2010 report entitled "Study to Identify Practical Measures to Address Flooding on the Clare River")
- Outline flood damage analysis based on the examination of recorded data, photographic evidence and interviews conducted with stakeholders affected by the floods of November 2009
- Flood alleviation option analysis and recommendations together with consideration of cost benefit analysis prepared in accordance with guidelines prepared by the OPW for minor works schemes.

It should be noted that all levels referred to in this report have been converted to Malin Head Ordnance Datum.

2. Catchment Characteristics

2.1 The Study Area and its surroundings

The study area is located in the townlands of Carnmore East and Cashla along the R339 regional road which links Galway City to Monivea. The study area is defined as the area affected by flooding in November 2009, the extents of which are shown on Figure 2.1. The surrounding land falls generally in the direction of Galway Bay, with some local variations. There are no streams within the study area, which consists mainly of gently undulating agricultural land.

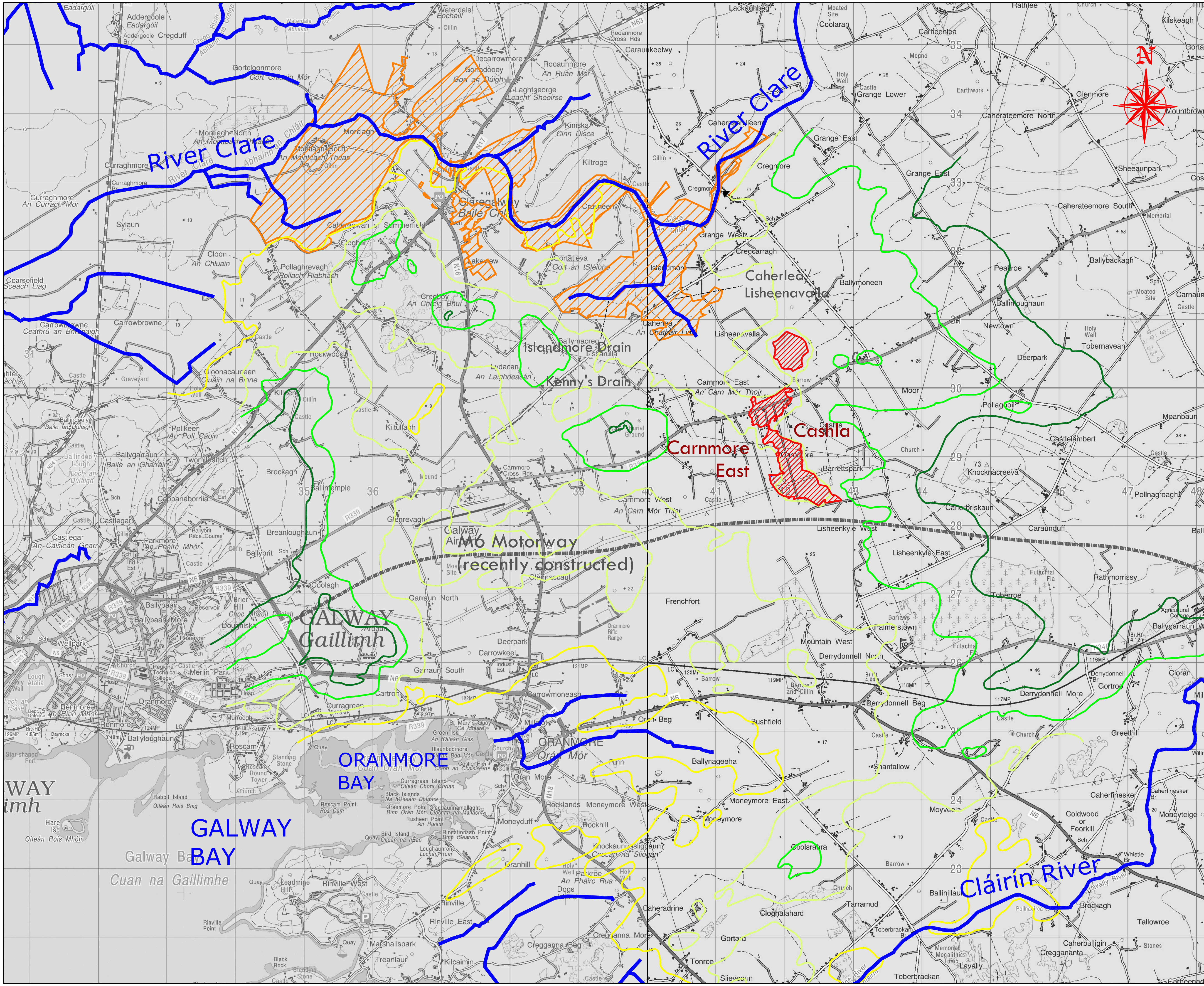
The primary surface water channels in the vicinity of the study area are the Clare River approximately 3km to the Northwest and the Clarin River approximately 6km to the South and Southeast. The Clare River is the largest river in the Corrib Mask River Basin, draining approximately 30% of the entire 3,056 km^2 catchment. The Clare River flows into Lough Corrib and the River Corrib, which flows from Lough Corrib, spills over the Salmon Weir in Galway City and discharges to Galway Bay at the Claddagh Basin. The Clarin River discharges directly to Galway Bay. The only other surface water channels between the study area and Galway Bay are the Loughannawillan Stream which flows from the Loughannawillan and Fishpond Springs in Frenchfort (Oranmore) and the Ballynageeha stream, both of which discharge to Oranmore Bay at Oranmore.

The land within the study area does not drain via surface water conduits to the Clare or Clarin Rivers as illustrated on the contoured maps in Figure 2.1. It is therefore apparent that drainage within the study area is principally by subterranean conduits.

The present day drainage networks in the region have been significantly influenced by arterial drainage schemes carried out since the early nineteenth century to reduce winter flooding. Figure 2.2 shows the drainage pattern of the Clare and Clarin River catchments prior to arterial drainage in the early nineteenth century (followed by two schemes in the 1950s and 1960s) and best reflects the natural drainage of the local Karstic region (the entire Karstic Region stretches from the Burren in County Clare, through much of County Galway, East County Mayo, Counties Roscommon & Sligo, North Leitrim and parts of Fermanagh and Tyrone). Prior to the construction the existing arterial drainage schemes, many streams within the present Clare and Clarin River catchments flowed underground or terminated in permanent or temporary lakes (turloughs) due to the karst limestone geology of east County Galway. These surface waters discharged underground and emerged later from springs further down the catchment. The Loughannawillan and Fishpond Springs in Frenchfort, Oranmore, are an example of this.

Karstic features in the study area include a shallow well and a seasonal spring at Cashla and caves and souterrains in Carnmore.

The arterial drainage schemes in the mid twentieth century involved the construction of numerous land drains, including one at Islandmore. The Islandmore Drain, the nearest surface water conduit to the study area, extends from its confluence with the River Clare upstream of the Crusheen Bridge through the townlands of Islandmore, Caherlea (along its boundary with Lisheenavalla) as far as the townland of Carnmore East, terminating within 1.2km of the study area,. The channel width ranges from approximately 2m wide at its upstream end in Carnmore East, where it is known locally as Kenny's Drain, to 5m upstream of its confluence with the River Clare. The Islandmore Drain has an average longitudinal gradient of 1 in 565. Lands in the vicinity of the drain suffered from flooding in November 2009 and a number of houses in Caherlea and Lisheenavalla were flooded. The extent of the flooding in of the River Clare, relative to the flooding in the study area, is shown on Figure 2.1.



LEGEND

Topographical Contours
(Levels to Malin Head O.D.)
10m
20m
30m
40m

Extent of Flooding at Carnmore Cashla

Extent of Flooding on River Clare

Local Rivers/ Streams

REV	DATE	DRN	DESCRIPTION	CHK	APD

REVISIONS

DRAWING STATUS
- ☐ PRELIMINARY
- ☐ CONTRACT
- ☐ TENDER
- ☐ PLANNING
- ☐ CONSTRUCTION
- ☐ FOR APPROVAL
- ☒ FOR YOUR INFORMATION
- ☐ AS CONSTRUCTED
- ☐ DRAFT

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue
Taylor's Hill, Galway
Tel:(091)587116 Fax:(091)587110
Email: rhc@ryanhanley.ie
Web: www.ryanhanley.ie
DUBLIN OFFICE: Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford, Dublin18.

CLIENT
Office of Public Works

PROJECT
Carnmore Cashla Flooding Report

TITLE
Location Plan Survey Area

SCALE @ A3	DATE	DRAWN	CHECKED	APPROVED
1:50,000	August 2010	J.R.	C.L.	C.L.

JOB No.		REV.
2138	Figure 2.1	

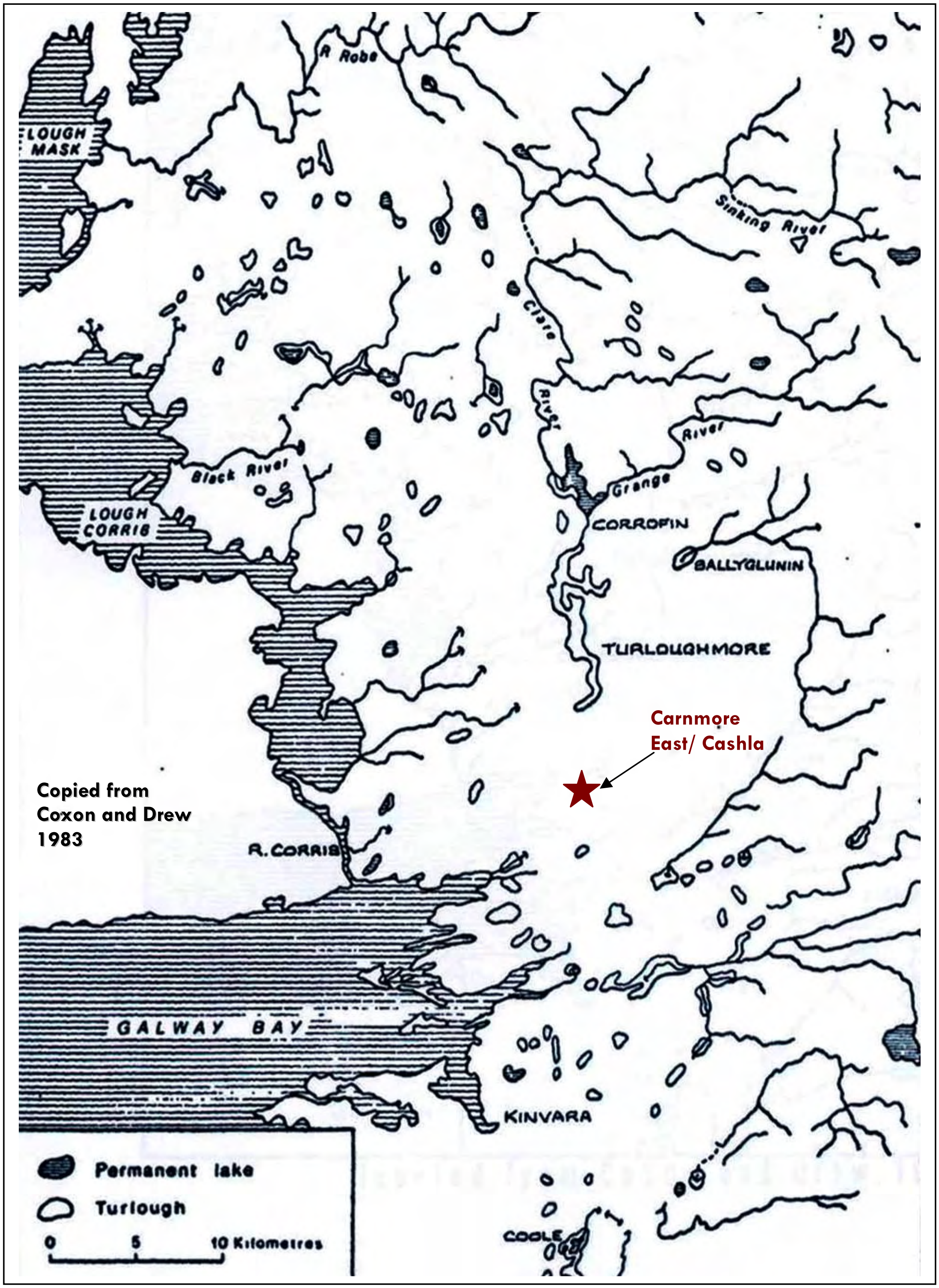


Figure 2.2 Drainage pattern within the present catchments of the Clare, Clarin & Dunkellin Rivers – Late 18th Century

2.2 Catchment Geology and Hydrogeology

A brief desk study of the catchment was carried out to assess the significance of the aquifer system in the catchment region and to quantify the winter rainfall acceptance potential of the overlying soils and sub-soils i.e. the ability for rainwater to infiltrate the soil.

The Geological Survey of Ireland (GSI) quaternary map indicates bedrock and shallow till as the overburden cover for the entire region east of the Corrib to Athenry including the study catchment. This quaternary is generally referred to as free draining. The Flood Studies Report (NERC, 1975) winter rainfall acceptance potential map, 1:625,000, was also consulted and this shows very high infiltration capacity for the catchment (SOIL type 1).

The catchment area is underlain by a pale to medium grey, bedded, fossiliferous, medium grained limestone called the Burren limestone (Daly, 1985). This limestone is generally pure with low clay content. It is often present at or close to the ground surface with only a thin cover of free draining sandy till (boulder clay). An extract from the GSI online River Basin District soils map is included in Appendix A and shows the bedrock in the area to be overlain by 'till derived chiefly from limestone'.

Pure limestones such as the Burren Limestone are susceptible to solution by groundwater moving through cracks in the rocks. The acid in rainwater reacts with the calcium carbonate in the limestone to form calcium bicarbonate. This is soluble and so is removed in solution thus enlarging the cracks in the rocks and causing the formation of widened conduits and caves. This solution of limestone, creating distinctive features of relief, hydrology and hydrogeology, is called karstification. Caves and souterrains, for example, are known to be located in Carnmore.

The whole catchment forms part of a Regionally Important Karstified (conduit) Aquifer. Karst features are located in the vicinity of the catchment, most notably the separate floods/turloughs which have led to the flooding in November 2009, which is the subject of this report. As noted previously, Karstic features in the vicinity of the study area include a shallow well and a seasonal spring at Cashla and caves and souterrains in Carnmore. The shallow Well in Cashla can be seen in Plate 2.1.

Plate 2.1 Spring Well at Cashla

The type of flooding experienced in karstified catchments can include flooding from springs, backing up of sinking streams with inadequate underground channel capacity or the flooding of closed depressions by rising groundwater.

Trial Holes

Two trial holes were excavated by locals with support from the OPW in the study area on 26th/27th January 2009. The purpose of excavating the holes was to establish the permeability of the sub surface layers at the location of Flood No.1 and investigate the possibility of alleviation of flood waters via an artificial sinkhole. The trial pits were excavated at the locations shown on Drawing No. 001 in Appendix B.

The first trial pit was dug down to weathered rock and a permeability test was carried out. Following this, the weathered rock was removed and a second permeability test was carried out. A second trial pit was excavated down to the top of a layer of impermeable clay, or 'daub' and a third infiltration test was carried out.

The first permeability test lasted for 50 minutes. In the second permeability test, which was carried out on the bedrock, the water took 11 minutes to dissipate. In the third test, which as carried out on a layer of daub, it is reported that the water took 24 hours to dissipate. The first trial pit was subsequently backfilled with stone and left as an artificial swallow hole. A month later, flowing a period of rainfall, approximately 10-15 acres of land around the trial hole flooded for 3-4 days.

It should be noted that these permeability tests are not necessarily representative of the overall characteristics of the subsurface layers within the study area. Photographs of the trial pits are sown on Plates 2.2 & 2.3.

Plate 2.2 Trial Pit No.1, Permeability Test No.2

Plate 2.3 Permeability Test on Trial Pit No.2

2.3 Ecology

There are no designated ecological sites within the study area, however any proposal that involves the alleviation of flood waters via discharge to the Islandmore Drain or in the direction of Oranmore would required ecological consideration.

The River Clare catchment forms a key component of the Lough Corrib candidate Special Area of Conservation (cSAC) which is selected for the numerous aquatic habitats and water-dependent species occurring there that are listed in Annex I and II of the EU Habitats Directive, including hard water lakes, lowland oligotrophic lakes, Atlantic salmon, White-clawed crayfish, Otter, Pearl mussel, Sea lamprey, Brook lamprey and Slender naiad.

The streams in Oranmore form part of the Galway Bay cSAC and Natural Heritage Area (NHA).

2.4 Meteorology

The mean annual rainfall at Galway (National University of Ireland, Galway) is 1147mm and at Athenry it is 1164mm. Rainfall duration, intensity and frequency tables for Galway are presented below in Table 2.1.

The rainfall data relating to specific flood events will be discussed in more detail in Section 2.7 of the report.

STATION NAME: GALWAY
RP5 60 min = 15.3mm
RP5 2d = 57.0mm
Annual Rainfall = 1147

Rainfall in mm for a Range of Duration and Return Period

	Return Period (Years)						
Duration	**½**	**1**	**2**	**5**	**10**	**20**	**50**
15 min	4.4	5.5	6.2	8.3	10.2	12.2	15.4
30 min	6.0	7.4	8.3	11.2	13.7	16.4	20.8
60 min	8.3	10.3	11.5	15.3	18.4	21.9	27.4
2 hr	11.0	13.6	14.9	19.4	22.9	26.7	32.6
4 hr	15.1	18.2	20.0	25.6	30.0	34.6	41.8
6 hr	18.8	22.5	24.3	30.8	35.7	40.6	48.6
12 hr	24.3	29.1	31.5	39.9	46.3	52.7	63.0
24 hr	30.9	36.3	39.7	49.0	55.9	63.7	74.5
48 hr	38.1	44.7	48.9	60.4	68.9	78.5	91.8

Table 2.1 Rainfall duration, intensity and frequency tables at Galway (NUIG)

2.5 Heritage

An online search of the Department of the Environmental, Heritage and Local Government (DEHLG) revealed that there are no recorded monuments within the study area with the exception of Monument Reference (GA083-007) in Crooknashammer which is described as a 'redundant record'. More significantly there are no recorded monuments on or close to a possible drainage route to the Islandmore Drain. Any drainage route in the direction of Oranmore would, however involve excavation in the vicinity of national monuments in the townlands of Carnmore, Derrydonnell and Frenchfort.

2.6 Historical Flooding

There is a history of flooding in the study area including the most notable flood events of recent times in November 2009 and (circa) 2000. The only evidence available is anecdotal and is discussed in Section 3.4 of this report. In summary, there was a particularly high flood thirty years ago which reached approximately 19.5 m O.D. (the level of the foundations of a house which was under construction at the time and has since flooded in November 2009) and there have been approximately five high floods in the past twenty years. A 'high flood' was described by residents of the area as a flood depth of between1 – 1.5 feet on the R339 regional road, which would not involve flooding of houses. This would equate to a flood depth of approximately19.4m O.D. It is believed that the flood in 2000 would be considered as one of the five 'high floods' in the past twenty years.

The main topic of this study is the flood event of November 2009 and this is discussed in Section 2.7.

2.7 November 2009 Flood Event

A brief description of the November 2009 flood event and the extreme rainfall event that caused the flooding is provided here in the context of the other historical flooding described above. Further detail and description of the cause, mechanism of flooding and flood impact is provided in later sections of this report.

2.7.1 High rainfall recorded in the region prior to the November 2009 flood

It is worth noting that the extreme rainfall recorded in November 2009 was preceded by a notably wet summer. Rain or showers were recorded on every day during July 2009. It was the wettest July for over 50 years in many places and the wettest on record at a number of stations. By the end of July, Met Éireann soil moisture records show that the land was almost completely saturated. 161.1mm of rainfall was recorded for the month at NUI, Galway which represented 237% of the monthly average. Rain fell on 26 days of the month, with a peak daily rainfall of 23.7mm recorded on the 5th July.

After this very wet July, August was another month of very unsettled weather with rainfall totals well above normal. 215.7mm of rainfall was recorded for the month at NUI, Galway, representing 214% of the monthly average. Rain fell on 27 days of the month with 28.9mm recorded on 30th August alone. The wet weather of August extended into the first week of September when some heavy rainfalls were recorded which caused flooding in some parts of the country as soil conditions were saturated. Overall, the rainfall for the summer season (June, July, August) 2009 was up to 175% above average for the mid Galway region.

It was therefore most likely that the region was above normal saturation levels by the end of summer 2009 prior to the commencement of the prolonged rainfall in October/November 2009.

October/November 2009 was notable for the high rainfall recorded and the consequent severe flooding experienced in many parts of the country. Atlantic depressions passing close to Ireland brought wet and windy conditions throughout almost all of November, continuing a pattern of very unsettled weather over Ireland which began in the middle of October.

The 18th to 31st October was a period of unsettled weather as a series of Atlantic depressions and their associated fronts moved across Ireland. The heaviest rain was measured on the 19th/20th, 24th and 30th, with widespread heavy showers also on the 21st and 22nd.

From November 1st to 26th, a series of fast moving deep Atlantic depressions brought active frontal systems across Ireland, bringing very wet and windy conditions. Spells of rain or showers gave falls of 10mm or more on many days across Connacht and Munster, while all areas received heavy falls on the 1st, 9th, in the period 16th to 19th and on the 21st. The **total monthly rainfall for November 2009** at NUI Galway was 465mm, approximately **300% of normal** November rainfall.

Daily rainfall amounts for November 2009 are shown on Figure 2.3 for NUI, Galway. The heaviest rain fell on the 17 November 2009 with 60.8mm of rain recorded on this day alone. This is the highest daily rainfall amount on record at this station. A further 28.7mm fell on the 18 November giving a two day rainfall total of 89.5mm. The next highest daily rainfall amount recorded during any of the historical flood events described above was 35.9mm recorded on 21 December 1999. Met Éireann agro-meteorological data shows that by the 10th of November, soil moisture deficit was zero, meaning that the capacity of the ground to accept rainfall had been reached. It is worth noting in the case of the study area in question that it continued to rain on the remaining days in November with the exception of the 28th & 29th.

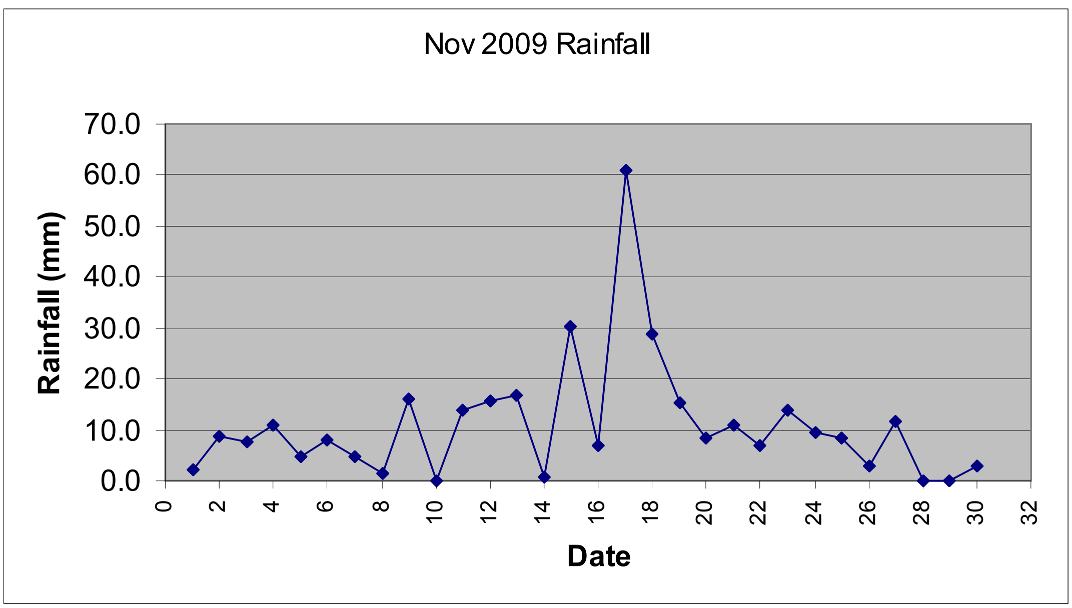


Figure 2.3 Daily recorded rainfall depths recorded at NUIG – November 2009

2.7.2 The Statistical significance of the extreme rainfall event that preceded the November 2009 floods

Met Éireann has carried out an analysis of the rainfall data in November and has estimated rainfall return periods for the study area.

The data in Table 2.2 is an extract from Appendix 1 of Met Éireann's Climatological Note No. 12 "Report on Rainfall of November 2009" for the NUIG Meteorological station in Galway City.

Rainfall Event	Estimated Return Period of rainfall event
1 day duration - 17 Nov 09	**29** years
2 day duration - ending 18 Nov 09	**134** years
4 day duration - ending 18 Nov 09	**293** years
8 day duration - ending 19 Nov 09	**306** years
16 day duration - ending 24 Nov 09	**272** years
25 day duration - ending 26 Nov 09	**131** years

Table 2.2 Estimated Rainfalls Return Period – November 2009

The flooding in Carnmore/ Cashla was caused by high groundwater levels in a karst region. Groundwater levels are slower to react to rainfall than levels in surface water conduits such as rivers. They generally take longer to peak and to subside. The high rainfall in the months preceding the events in November 2009 are quite significant in that they contributed to a higher than normal water table. The prolonged intense rainfall in November 2009 contributed to a further rise in water levels in the study area, the extent of which has not been recorded in recent history. Figures 4(a) to 4 (f) of Met Éireann's Climatological Note No. 12 "Report on Rainfall of November 2009" are maps of Ireland which show the area of the country where rainfall of particular statistical significance in terms of return period was recorded during November 2009. The area of the country, where rainfall events of 4, 8, and 16 day duration was significant, extended in a north easterly direction from Galway City towards County Roscommon and included the upper Shannon Catchment.

2.7.3 The effect of flooding in November 2009

Historical flooding in the Carnmore East/ Cashla area takes place at three locations and these are shown on Figure 2.1 and Drawing No.001, which is contained in Appendix B. This report focuses on Flood Nos. 1 & 2, as shown on Drawing No.001. Flood No.3 inundated agricultural land but did not present any threat to houses or roads.

Flood No. 1 is a turlough which originates approximately 1km south of the R339. In November 2009, the turlough expanded to cover an area of approximately 0.5 km^2 and came within 260m of the R339, overflowing into Flood No. 2 during the flood event. A quarry is located at the southeast end of the turlough. Aerial photographs of the flooding support the anecdotal evidence of local residents who contend that flood waters were pumped from the open quarry into the turlough during the flood event. The water level in the quarry can be seen to be lower than that in the surrounding land, in Plate 2.4 for example. The new M6 motorway is routed approximately 200m to the South of Flood No.1. Immediately to the North of the turlough are two houses (House Nos. 9 &10 as shown on Drawing No.001) and farm buildings. House No.9 was in danger of flooding in November 2009. It was not possible to establish timescale for Flood No.1 in November 2009. Given the interconnection between Floods No. 1 & 2, the levels of the two the floods are likely to have equalised prior to the peak flood level, possibly around Saturday 21st November 2010. Aerial photography of Flood No.1 is shown in Plate 2.4.

Plate 2.4 Aerial Photography of Flooding in November 2009 (taken from Southeast)

Flood No.2 originated in a field (Referred to locally as Beatty's field) adjacent to the R339. In November 2009, the flood expanded to cover an area of approximately 0.2 km^2 including a 620m long stretch of the R339. As noted in the description of Flood No. 1, the two floods joined together during the flood event, with Flood No.1 overtopping into Flood No.2. Four houses (one of which is derelict) were flooded as a direct result of this flood and a further seven houses and two business premises were put at risk of flooding. Flood No.2 also forced a two-week long closure of the R339, with the depth of flood waters exceeding 1m, contributed to a 7m long crater on the L31013 local road and prevented access to four houses on the L71116 and five houses on the L71119 local roads. Local businesses, including Greaney Glass Ltd & Newell Roofing Ltd were also disrupted.

In the case of Flood No.2, it was reported by residents of the area that water began to flow forcefully from a field corner adjacent to House No.5. The ground level in the corner of the field in question is approximately 19.4m O.D and the road level outside the field is approximately 19.7m O.D. The water flowed westward along the R339 and around the back (South) of House No.5 into the main body of Flood No.2, without initially flooding House No.5. The flood waters congregated in Beatty's field where the flood level there was augmented by the overland flow from the spring adjacent to House No.5. At the opposite end of the 'spring' field, there is a shallow well, which when observed during Ryan Hanley's site visit in July 2010, contained a relatively shallow water level. House No.5 subsequently became one of the three houses which flooded. Similar accounts were given for water which emerged from a field to the South of House No.12. The water flowed overland and under the raft foundations of the house, bubbling up through the loose stone to the front (North) of the house before flowing in the direction of Flood No.2.

It can therefore be concluded that Flood No.2 resulted from a combination of springs to the East and South of House Nos. 5 & 12 with flood waters congregating at Beatty's field. It cannot be said for certain if a turlough would have formed in the absence of overland flow from the springs to the East of the study area. Flood No.2 had the most serious consequences of all 3 floods in the study area.

There follow, in Plates 2.5 – 2.9, some photographs of Flood 2, which were taken in November 2009, the first two of which are aerial photographs taken from the East southeast.

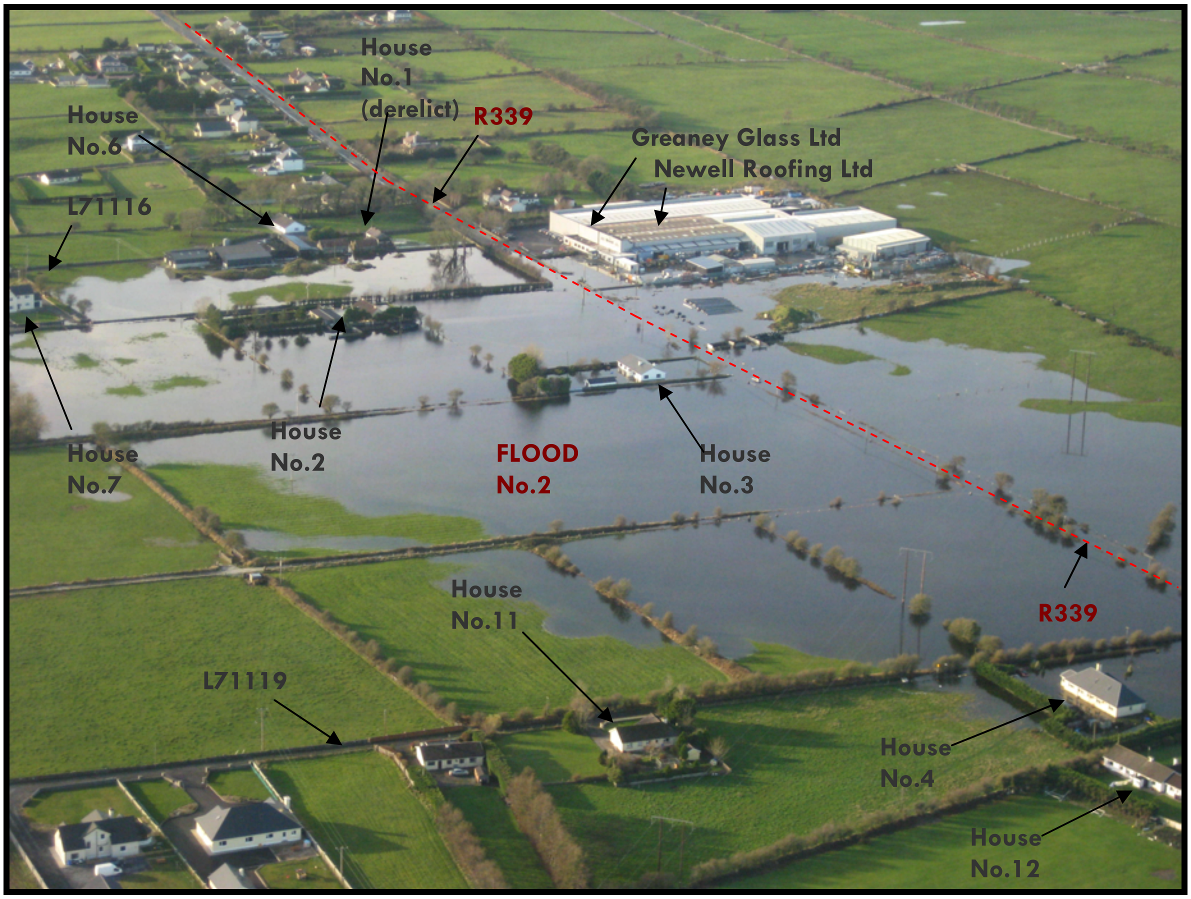


Plate 2.5 Aerial Photography of Flooding in November 2009 (taken from east southeast)

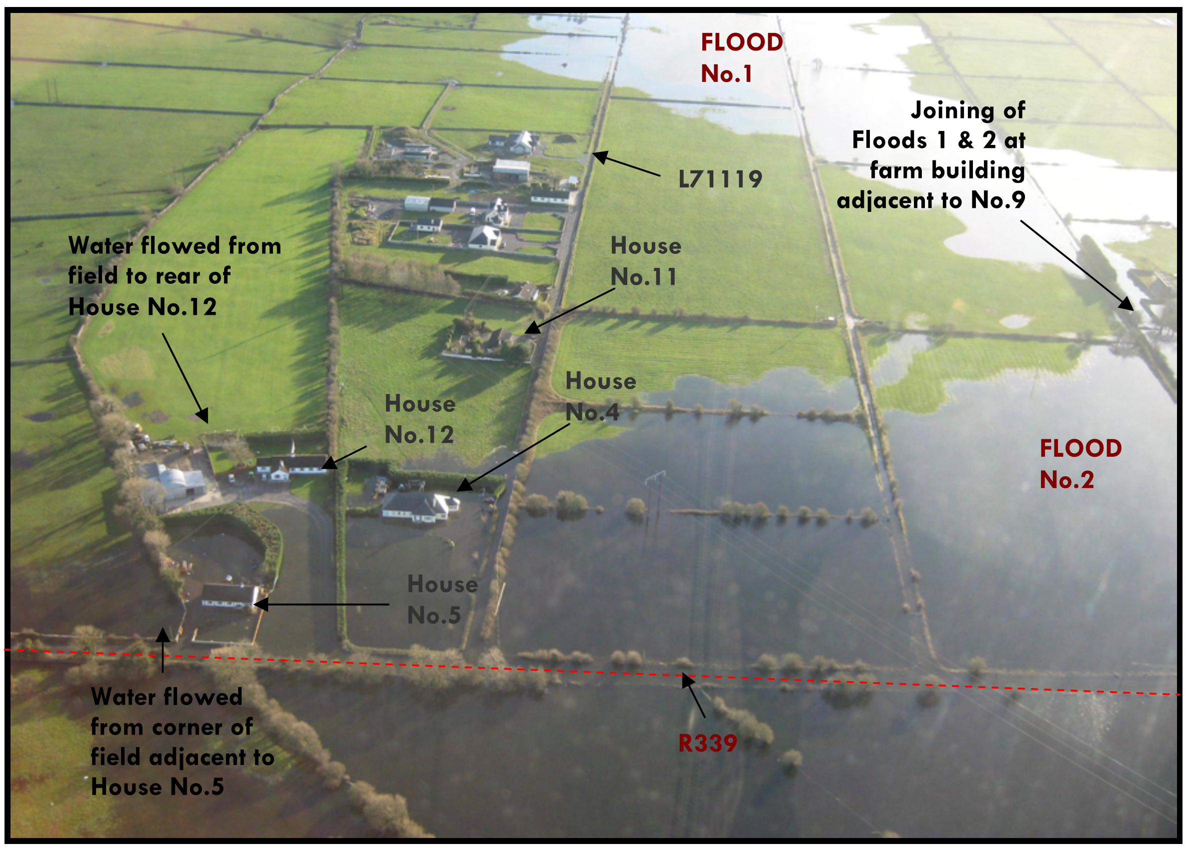


Plate 2.6 Aerial Photography of Flooding in November 2009 (taken from North)

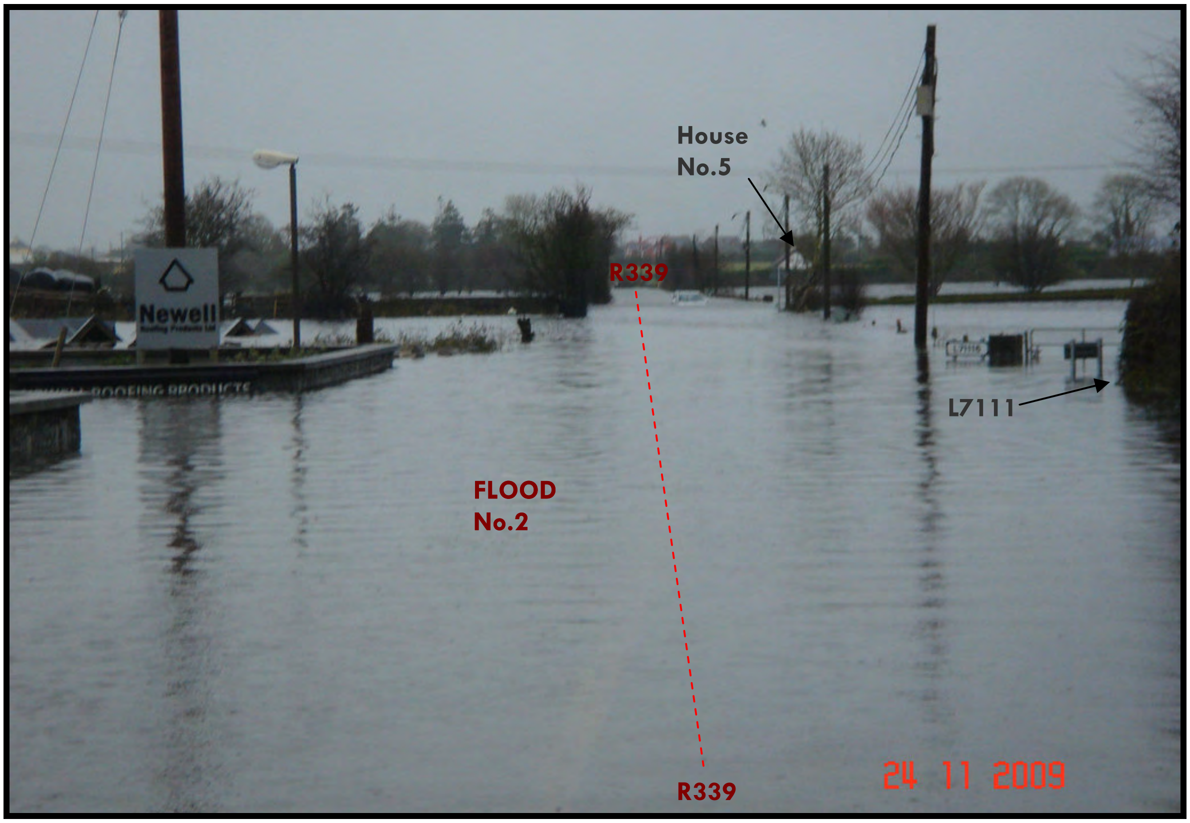


Plate 2.7 Photograph of Flooding on R339 in November 2009
(Taken outside Greaney Glass Ltd, looking east)

Plate 2.8 Photograph of Flooding on R339 in November 2009
(Taken within Newell Roofing Ltd premises, looking east southeast)

Plate 2.9 Photograph of Flooding to South of R339 in November 2009
(Taken on road outside Greaney Glass Ltd, looking south southeast)

3. Data Collection

3.1. General

Data has been collected in order to predict the peak flood levels and return periods for the November 2009 flood and to inform the findings of the study as described in the sections below.

3.2. Meteorological Data

The nearest Met Éireann rainfall station to the catchment is at the National University of Ireland, Galway in Galway City, approximately 10 km away. Daily rainfall totals were obtained for this station for the significant flood events of recent years as well as for the November 2009 flood event. Daily rainfall records were also obtained for the rain gauge at the OPW offices in Headford, Co. Galway. The Met Éireann archive of monthly weather bulletins was also consulted particularly for the significant flood events.

3.3. Surveys

In order to better understand the dynamics of the flood at Carnmore East & Cashla, topographical surveys were carried out for the areas covered by Flood Nos. 1 & 2, a 1.3km stretch of the R339 & L31013 and also for finished floor levels (FFLs) of houses in the study area. A topographical survey was also carried out in order to establish the optimum route of any potential drainage channel to the Islandmore Drain.

An initial survey of the areas covered by Flood Nos. 1 & 2 was carried out by the OPW in early 2010. Ryan Hanley subsequently visited the site and carried out a topographical survey of the R339, L1013, the land between Flood No.2 & the Islandmore Drain, while also calibrating the information received from the OPW by verifying FFLs of houses in the area. During the site visit Ryan Hanley engaged with local residents in order to establish the level to which the flood reached in 2009. It has been established that the flood reached a level of approximately 20.1m O.D. The basis for this is set out in Section 3.4.

The information obtained from the topographical survey was used to produce contour mapping of the study area together with longitudinal sections of the R339 & L31013 roads and of a proposed flood alleviation drain. This survey information is shown ion the drawings appended to this report.

3.4. Anecdotal Evidence

A significant volume of anecdotal evidence was collected relating to the November 2009 and other significant flood events. The evidence was collected in a number of ways including meeting local residents, both at a meeting held at Danny and Marion Potter's house on 16th July 2010 and during a further site visit on 20th July 2010.

The table below provides a summary of the pertinent information collected from local residents, business owners and local representatives;

1. Prior to November 2009, a high flood in 2000 was the most recent of five high floods in the past twenty years. A high flood was described as one which results in a flood depth of between 1 & 1.5 feet on the R339.
2. Thirty years ago, when House No.3 was under construction, a flood came in over the foundations of the house.
3. The residents of the first two houses (House Nos. 2 & 3) to be flooded in November 2009 moved out of their houses on Thursday, 19th November 2009.
4. Water entered House No. 2 in the early hours of 19th November 2009. It did not enter through the doors to the house, which were protected with sandbags.

5. Water entered house No. 3 at approximately 10/11 A.M. on 19th November 2009. Again, it did not enter through the doors to the house, which were protected with sandbags. The water level had risen to a depth of 6" – 9" by 7 o'clock that evening.
6. The residents of House No. 5 moved out on Thursday, 19th November 2009, although the house had not flooded at that stage. They returned to their house two days later to find that the flood waters had risen under the floorboards in the house. The peak flood depth of 11 inches above floor level occurred on an unspecified date during the following week.
7. The flood water continued to rise gradually until Saturday 28th November 2009. The flood started to recede slowly from Sunday 29th November through to Wednesday 2nd December 2009. The floods dissipated almost completely over the following 24 hours.
8. The flood waters disappeared within hours in the end.
9. "Malachy's field" (Flood No. 1) was the first area to flood within the study area. It had flooded for 2 or 3 days prior the commencement of Flood No.2.
10. Beatty's field was the first area to flood in the vicinity of the R339 (Flood No. 2) as has been the case with other recent floods in the study area.
11. Water began to flow from the corner of the field adjacent to (East of) House No. 5 in the days prior to the residents moving out on 19th November and began to flow westward along the R339, accumulating initially at Beatty's field.
12. Water began to flow from the North end of the field behind (South of) House No. 12 in a north westerly direction. The water did not flood House No. 12, however it could be seen bubbling through the loose stone immediately in front of (North of) the house.
13. The following flood levels were reported;
    a. A flood depth of approximately 15" was reported in House No. 1, although it is worth noting that this house is derelict. This equates to a flood level of approximately 20.02m O.D.
    b. The flood rose to a depth of 22.5" above Finished Floor Level (F.F.L.) in House No. 2. This equates to a flood level of approximately 20.10m O.D.
    c. The flood rose to approximately 22" in House No. 3. This equates to a flood level of approximately 20.15m O.D.
    d. The flood rose to a depth of 11" in House No. 5. This equates to a flood level of approximately 20.10m O.D.
    e. The flood came to within 1" of entering the premises of both Newell Roofing and Greaney Glass. This equates to a flood level of approximately 20.17m O.D.
    f. The flood surrounded but did not enter House No. 4. A flood level of approximately 20.05m O.D. was reported at this location.
    g. The flood rose to a level on the road sign for the L71116 and an adjacent gate that equates to a flood level of approximately 20.20m O.D.
    h. The flood rose to a level of approximately 20.12m O.D. at House No. 9 and the yard adjacent to the same house.
    i. The flood entered the driveway of House No. 13 and rose to a level of approximately 20.03m O.D.

14. A 70m long section of the L31013 was covered by flood waters from Flood No. 2 and a 7m long section was badly damaged as a result of the high water levels and traffic loading.
15. It is reported that water was being pumped from a quarry at the south eastern end of Flood 1 (see Drawing No.001 in Appendix B), during the November 2009 flood. A local depression in the water table within the open quarry is apparent from the aerial photography available. There is a widespread perception and strongly held views that this was a contributing factor to the flooding in the study area.
16. Residents also expressed their concern that the construction of the M6 motorway to the South of the study area was a contributing factor to the November 2009 flood.

Some of the issues raised above cannot be dealt with in this study as they are outside the scope of this report. These include the consequences of the pumping from the quarry and the construction of the M6 motorway.

Details of the houses and their owners are summarised below;

House No.	Owner	F.F.L. (m O.D.)	Flooded	Reported Flood Depth
1	Padraig Conneely	19.64	Yes	15 inches
2	Michael Flaherty	19.524	Yes	22 1/2 inches
3	Danny Potter	19.59	Yes	22 inches
4	Martin Joe Feeney	20.254	No	
5	Ned Keogh	19.814	Yes	11 Inches
6	Mary Conneely	21.53	No	
7	Peadar Conneely	20.65	No	
8	Marie Conneely	~20.65	No	
9	Gerry Hanley	20.10	No	
10	Peadar Conneely	-	No	
11	Martin Joe Feeney	21.17	No	
12	John Greaney	20.30	No	
13	Thomas Collins	20.54	No	
14	Mr Collins	20.96	No	

Business No.	Name	F.F.L. (m O.D.)	Flooded
15	Greaney Glass	~20.15	No
16	Newell Roofing	~20.15	No

3.5. Other Sources of Information

Aerial photography was obtained from the local residents for the flooded areas. The extent of the flooding identified in the aerial photographs was then transferred into AutoCAD and is shown on Figure 2.1 & Drawing No. 001. It should be noted that this does not represent the peak flood in the study area, as verified by contour mapping and observations regarding peak flood levels. The flood peaked approximately two days earlier.

The online database of Geological Survey Ireland (GSI, www.gsi.ie) was consulted in order to obtain more information on soil types and the local groundwater aquifer. Extracts from this are included in Appendix A. The online database www.floodmaps.ie was also consulted, however this contained little information on the flooding at Carnmore/Cashla.

Additional maps which were consulted include the 1915 & 1840 Ordnance Survey maps for the mid Galway region and a location map for the new M6 motorway, the route of which is plotted on the drawings contained within this report. The old Ordnance Survey maps sometimes contain information which has not been transferred to modern maps, such as information on historical flooding or karst features.

Information was also sought and obtained regarding the trunk watermain which was laid along the R339 to supply water from the Tuam Regional Water Supply Scheme to Athenry, so that any effect that a proposed flood alleviation pipe would have on this watermain could be planned for.

4. Flood Flow Estimation

4.1. Methodology

No surface water courses existing within the study area. The flooding resulted from a rise in groundwater levels.

The nature of groundwater flow is complicated and is affected by a variety of factors including topography, depths of subsurface layers (including rock), their permeability and local surface water conduits, where these exist.

The anecdotal evidence which exists relates only to the November 2009 flood. The timescale of the floods have been established by talking to residents who were able to identify critical incidents during the flood and the times at which they occurred, for example the time of day on the 19th of November that the flood waters entered a certain house, or the time of day that the floods reached a critical level within the study area.

Given the complex nature of groundwater flow, the most reliable method of calculating the rate of peak flow of flood waters into the study area involves using the information available on flood levels and the times at which they occurred (See Section 3.4).

The volume of flood water (i.e. water stored above ground) in the study area was calculated using contour mapping, which in turn was produced using information obtained from the topographical surveys carried out by Ryan Hanley and the OPW. The volumes of flood water corresponding to a variety of flood levels were calculated and these were then compared with the timescale of the flood provided in anecdotal evidence from local residents.

The design flood in this case is determined using a simple equation, as follows;

$Q = V/t$

where;

Q= the design flow (m^3/sec)

V = the volume of flood water in the study area (above ground)

t = the length of time it took for the flood water reach a certain volume, V.

4.2 Calculation of Peak Flow of November 2009 Flood

The timescale of the flooding and corresponding flood volumes are presented in the following table and associated graph;

Date	Time	Description	Level (mO.D.)	Volume (000 m³)
17/11/2010	-	Beatty's field began to flood approximately 2 days prior to the evacuation of residents from the study area.	18.60	0
19/11/2010	06:00	Mr. Mick Flaherty awoke to find water on the floor of his bedroom in House No.2 at approximately 6.A.M. The water rose through drains/ the floor of the house.	19.50	68
19/11/2010	10:00	Flood water began to enter House No.3. The flood entered via plumbing according to Mr. Danny Potter.	19.59	81
19/11/2010	19:00	Flood waters in House No.3 reached a level of 6" to 9". A level of 8" has been assumed for our volumetric calculations.	19.79	113
21/11/2010	-	Mr. Ned & Mrs. Margaret Keogh returned to House No.5 to discover that water had risen under but had not yet risen above the floor boards.	19.81	117
28/11/2010	-	Mr. Danny Potter reported that the flood waters were still rising on Saturday 28th November but that they began to recede the following day.	20.10	176

Table 4.1 Timescale of November 2009 Flood

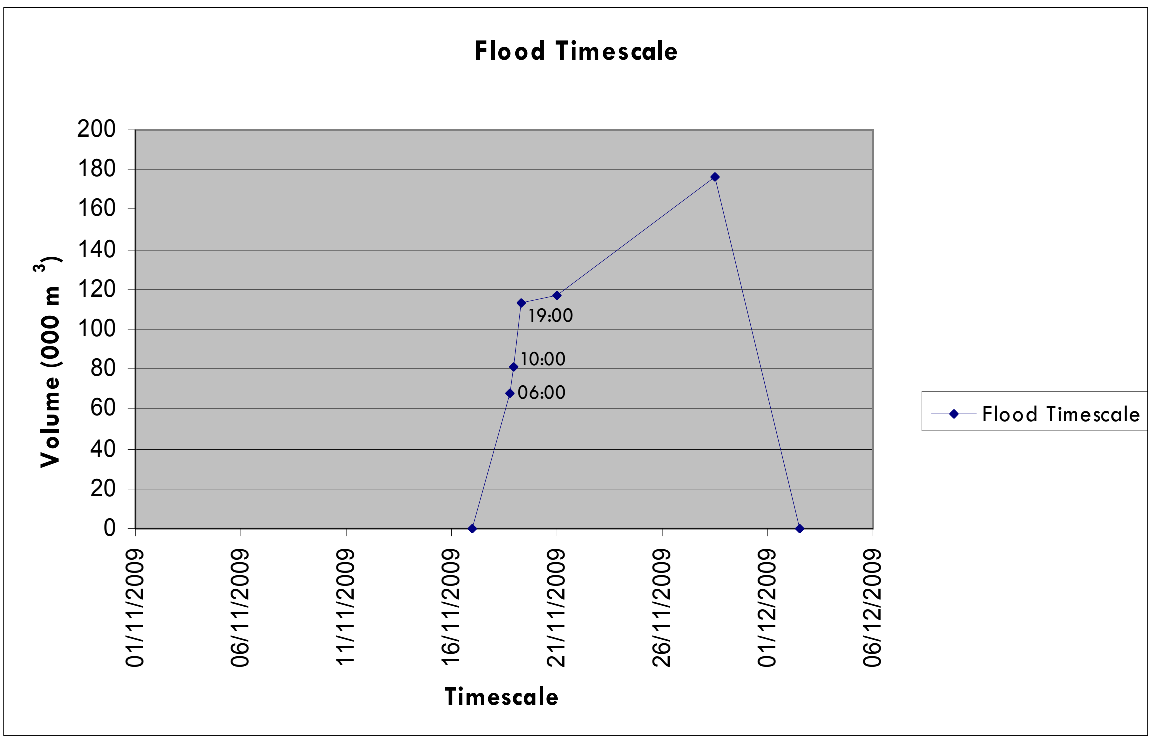


Figure 4.1 Timescale of November 2009 Flood

Integrating Figure 4.1 & Figure 2.3 (presented previously in Section 2.7 of this report), we can see the response of the water levels to the rainfall in the mid Galway region for the later half of November 2009.

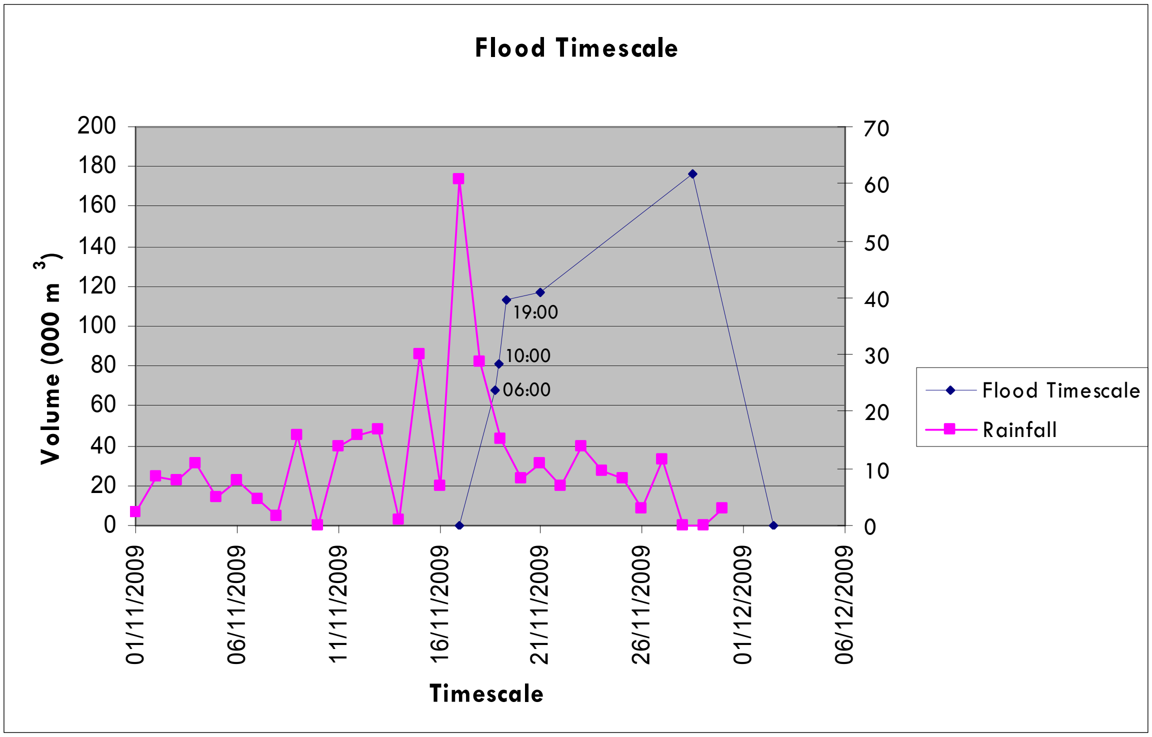


Plate 4.2 Timescale of November 2009 Flood including rainfall (in millimetres)

It is clear from observing Figure 4.2 that the volumes of flood water in the study area increased most rapidly from the 17th to the evening of the 19th of November, notwithstanding variations in the actual flood levels that could be attributed to the nature of anecdotal evidence. It is likely that the flood reached the F.F.L. of House No. 2 prior to the discovery of water in the house at 6 A.M. on 19th of November 2009. The figure of 8" of water in House No.3 at 7 P.M. of the same day is also thought to be conservative. The actual timescale for the rise of flood waters from 19.50 to 19.79 is almost certainly longer.

The flow of groundwater into the study area between 6.A.M. and 7.A.M. on 19th November 2009 is therefore a conservative estimate of the peak inflow to the study area, and is calculated as follows;

$Q_{(1-2)} = (V_1-V_2)/(t_1-t_2)$

$Q_{(1-2)}$ = The flow into the study area between 6.A.M. & 7.A.M. on 19th November 2009 (m^3/sec or cumec)

V_1 = Volume of Flood No.2 at 7 P.M. on 19th November 2009 (m^3)

V_2 = Volume of Flood No.2 at 6 A.M. on 19th November 2009 (m^3)

(t_1-t_2) = The time between 6 A.M. & 7 P.M. (seconds)

$$Q_{(1-2)} = \frac{(113-68)*1000}{(19-6)*60*60}$$

$Q_{(1-2)} = 0.96\ m_3/sec$

4.3 Discussion of Peak Flow of November 2009 Flood

The figure of 0.96 m^3/sec is a conservative estimate of the rate of inundation of the study area with flood waters at the peak of the November 2009 Flood, i.e. between 6 A.M. and 7 P.M. on Thursday 19th November 2009.

The design flow for the capacity of a flood alleviation pipe is consequently taken as 1 cumec (1 m^3/second).

5. Flood Damage Analysis

5.1. General

A Flood Damage Analysis is described below for the November 2009 flood event based on the anecdotal evidence collected.

5.2. Flood Mapping

The extent of the inundation resulting from the flood of November 2009 is shown on the Drawing No.001 in Appendix A. The flood extents shown on the drawing are based on aerial photography taken circa 30th November 2009 although the peak of the flood occurred two days earlier. This drawing denotes flooded properties, properties at risk of flooding and properties cut off by flooding. Roads flooded in the November 2009 event are shown on Drawing No.002 in Appendix B.

5.3. Assessment of Impact of Flooding

5.3.1 Summary of Impacts consequent to November 2009 flooding

The drawings referred to above give an overview of the impact of the November 2009 floods. As well as showing the extent of the flood, these drawings show houses which were flooded, houses which were at risk of flooding and roads that were flooded and impassable as a result. These impacts will be the input to the Flood Risk Assessment and the Outline Flood Damage Analysis described below in this Chapter.

Ref.	Effect	Qty.
1.	Houses Flooded at Carnmore East/ Cashla	3 No. (+1 derelict)
2.	Houses not flooded but at Risk of Flooding	7 No.
3.	Business Premises not flooded but at Risk of Flooding	2 No.
4.	Houses cut off by flooding (R339)	3 No.
5.	Houses cut off by flooding (L71116)	4 No.
6.	Houses cut off by flooding (L71119)	6 No.
7.	Houses cut off by flooding (L31013)	1 No.
8.	Regional Road Flooded >1m (R339) from 18th November to 2nd December (14 days)	660m
9.	Local Road Flooded ~ 250mm (L31013), with damage caused to road deepening the flood and making road impassable at the peak of the flood.	80m
10.	Local Road Flooded ~ 800mm (L71116) for approximately 13 days	220m
11.	Local Road Flooded ~ 1m (L71119) for approximately 14 days	110m

Table 5.1 Description of Flood Impact – November 2009 Flood

5.3.2 Estimation of flood damages and benefits accruing from flood alleviation options

Based on the table above, an outline flood damage analysis has been conducted for the November 2009 flood based on the benefit allowances allowable for OPW minor works schemes. For this assessment, homes at risk at flooding are defined as homes for which the peak flood level was within 500mm of finished floor level.

Assessment of Benefit
€25,000 per existing home that has been flooded
€10,000 per existing home at risk of flooding
€30,000 per flooded commercial property
€160 per day for each home cut off by flooding
€400 per hectare of land continuously flooded for at least 1 month
€20 per journey where a diversion of greater than 30 mins is caused by flooding

Table 5.2 OPW Benefit Allowances

The closure of the R339 road had a severe impact on other commuter routes to Galway city that remained passable during the November 2009 event. Other routes into Galway City became heavily congested and this was exacerbated by the closure of the N17 in Claregalway, the N18, the N6 in Craughwell, two of the three roads linking Athenry to the R339, the local road in Lisheenkyle to the South of the R339 and other minor roads in the region including the local road to the North of the study area that passes through Lisheenavalla. Delays of several hours were encountered on the N84 route as a result of the diverted by commuter traffic. The M6, which was under construction at the time, was opened prematurely from Galway to Ballinasloe to alleviate some of the traffic congestion at a cost to the taxpayer. Commuters were unable to report for work on time and were forced to leave early in order to return home.

The outline damage analysis for the November 2009 flood is based on the following facts and assumptions;

- The timescale of the flooding ascertained from anecdotal evidence provided by local residents has provided enough information to determine the periods during which roads were closed.
- The R339 remained closed for a fortnight.
- The closure of the R339 and flooding of carpark and stock yard of Newell Roofing caused severe disruption to the business of Newell Roofing for 14 days. The vehicular entrance to Greaney Glass is higher than that the entrance to Newell Roofing and was not flooded in November 2009, however the R339 was closed and this would have caused considerable disruption to business. It is therefore assumed that the business of Greaney Glass was disrupted for the equivalent of half that period.
- The daily average number of journeys taken on the R339 West of the Carnmore Cross Roads in 2009/2010 is in excess of 9,000. A figure of 9,276 for 2010 was quoted in the Oral Hearing for the Galway City Outer Bypass. It is assumed that one third of these journeys transferred through the Carnmore Crossroads to the R339.
- Claregalway also remained impassable for the first week of the flood on the R339. It is therefore assumed that all of the diverted journeys in the first week were in excess of 30 minutes and that this figure dropped to approximately 500 journeys per day for the duration of the second week. 3,000*7 + 500*7 = 24,500 journeys.

The cost of damages for the "Do Nothing" scenario i.e. carrying out no works, will be used later in the study as input to the cost benefit analysis of each of the potentially viable flood risk management measures.

Table 5.3 provides a summary of the estimated economic cost of damages or the benefit for each category in respect of the November 2009 flood event.

Ref.	Location	Outline Damage Analysis						
		Flooded Residential Property	Properties at Risk of Flooding	Flooded Commercial Property	Houses Cut Off by Flooding (per day)	Flooded Land (hA)	Traffic Diversions	Benefit (€)
		25000	**10000**	**30000**	**160**	**400**	**20**	
1	Houses Flooded	3	-	-	-	-	-	**75,000**
2	Houses at Risk of Flooding	-	7	-	-	-	-	**70,000**
3	Business Premises at Risk of Flooding	-	2	-	-	-	-	**20,000**
4	Houses cut off by flooding (R339)	-	-	-	42	-	-	**6,720**
5	Houses cut off by flooding (L71116)	-	-	-	56	-	-	**8,960**
6	Houses cut off by flooding (L71119)	-	-	-	72	-	-	**11,520**
7	Houses cut off by flooding (L31013)	-	-	-	2	-	-	**320**
8	Flooding of R339, 660m	-	-	-	-	-	24500	**490,000**
9	Flooding of L31013, 80m	-	-	-	-	-	-	**-**
10	Flooding of L71116, 220m	-	-	-	-	-	-	**-**
11	Flooding of L71119, 110m	-	-	-	-	-	-	**-**
12	Land Flooded	-	-	-	-	100	-	**40,000**
	TOTAL (#)	**3**	**9**	**-**	**172**	**100**	**24,500**	
	TOTAL (€)	**75,000**	**90,000**	**-**	**27,520**	**40,000**	**490,000**	**722,520**

Table 5.3 November 2009 Flood Event Outline Damage Analysis – Do Nothing Scenario

6. Alleviation Options

6.1. General

The impacts of the November 2009 flood event are analysed and evaluated where possible in Chapter 5. This chapter discusses potential flood risk management measures to mitigate the impacts of floods of this magnitude.

A range of potential flood risk management measures have been identified to mitigate the risks. The brief for this study calls for practical measures to eliminate or reduce flooding from an event similar in magnitude to the November 2009 event.

6.2. Potential Alleviation Options

There are numerous potential alleviation options which may be appropriate. The majority of the flood risk management options evaluated fall into the general categories listed below:

- Do Nothing
- Do Minimum (local site specific improvements)
- Non-structural Measures (Flood Warning System, provide individual protection of properties)
- Dissipation of flood waters within study area.
- Construction of flood alleviation drain to an outfall location outside the study area, such as;
  - The Islandmore Drain
  - Oranmore

In November 2009, several houses operated barrier methods, such as use of sandbags, to try and keep the water out, however these did not prevent the flood water entering these houses as the water came in through drainage pipes and through the floors. The houses in question were constructed on strip foundations. Other houses in the area did not suffer from flooding by virtue of the fact that they were constructed on raft foundations. It should also be kept in mind that a barrier method would do nothing to alleviate the flooding on the R339.

The disposal of flood waters to ground by constructing a sink hole was proved earlier this year not to work (See Section 2.2), when a trial hole excavated by locals and the OPW backed up with groundwater. Similarly, there are no viable local site specific improvements that will alleviate the flooding in the area.

This leaves the option of diverting the flood waters to a location outside the study area. Of these, only two, the drain at Islandmore and a stream in Oranmore have been identified as potentially viable options. These are screened for viability in Table 6.1.

The potential viability of the flood risk management measures considered will be assessed through a preliminary viability screening process whereby each measure will be examined in relation to the following criteria;

- Technical viability
- Economic viability
- Environmental viability
- Social acceptability

It is not feasible nor is it advisable to entirely eliminate flooding in the study area. Draining the flood waters to a separate location may increase the flood risk there.

VIABILITY SCREENING			
Potential Measure		**Drain flood water to Islandmore Drain (Kenny's Drain)**	**Drain flood water to Oranmore stream**
Viability Screening	**Technical Viability**	Technically possible given the local topography, however November 2009 also saw flooding in the Caherlea and Lisheenavalla due to backing up of water in the Islandmore Drain. Recommendations have been made in the "*Study to Identify Practical Measures to Address Flooding on the Clare River*" report to reduce the risk of flooding in the Caherlea and Lisheenavalla areas. No flood alleviation measures may be constructed for Carnmore East/ Cashla until the measures of that report are implemented.	Technically possible but would involve a longer drain, which would involve deeper excavations, a railway, a national road (N6) and a motorway crossing. November 2009 also saw flooding along the stream in Oranmore, and without flood alleviation downstream, it is inadvisable to dispose of additional flood waters in the area.
	Economic Viability	Should be viable subject to cost benefit analysis.	More expensive than alternative drain, due to topography and obstacles along drainage route.
	Environmental Viability	Negligible environmental impact.	Interaction with the Galway Bay cSAC.
	Social Acceptability	Acceptable once it is demonstrated that flood alleviation options put in place on the Clare River will facilitate a larger discharge to the Islandmore Drain without putting houses in the Caherlea Lisheenavalla areas at risk of flooding again.	Not acceptable unless it is demonstrated that flood alleviation options put in place at Oranmore will facilitate a larger discharge to the local stream without putting local houses at risk of flooding again.

Table 6.1 Viability Screening

Although both options are viable, the option of draining water to the Islandmore Drain is considered the better of the two. It is proposed that a spinal drain be constructed from a location between the first two houses to flood in November 2009 (House Nos. 2& 3), along a route which is as parallel to field boundaries as is practical, with an ultimate discharge to the Islandmore Drain approximately 2km to the North Northwest.

6.3. Preferred Alleviation Option – Discharge to Islandmore Drain

6.3.1 General

The function of a flood alleviation drain will be to reduce the risk of flooding of the houses in Carnmore East/ Cashla, while also reducing the frequency and severity of flooding on the R339. As noted in Table 6.1, it is recommended that this drain be constructed only when measures have been put in place to alleviate flooding in the catchment of the Islandmore Drain in the townlands of Caherlea & Lisheenavalla. Measures to achieve this, which were recommended in the "Study to Identify Practical Measures to Address Flooding on the Clare River" report, include channel widening of the Clare River to a point 900m upstream of Crusheen Bridge, modifications to the bridges in Claregalway and Crusheen and 'cleaning and limited re-grading of Islandmore Drain (OPW Refs. C3/7 & F.799/1)'. It should be noted at this point that the peak flood level at the bridge in Claregalway occurred on Sunday 22nd November (See Figure 2.12 of the "Study to Identify Practical Measures to Address Flooding on the Clare River" report), whereas the peak inflow to Flood No.2 at Carnmore East/ Cashla occurred on the 19th November.

Ryan Hanley carried out a topographical survey of land between the Islandmore Drain/ Kenny's Drain and the study area. The optimum route of a flood alleviation drain is shown on a plan and longitudinal section on Drawing No. 004. The finished floor level (F.F.L.) of the lowest of the houses in the study area is 9.52m O.D., while the lowest road level on the R339 is approximately 9.0m O.D. It is proposed therefore to construct a drain that come into operation once flood waters reach a level of 9.2m O.D., with a capacity which will equal that of the peak rate of inundation of flood waters experienced in November 2009. This peak flow rate was established in Chapter 4 as 1 m^3/sec (cumec) and the proposed drain would therefore require a minimum capacity of 1 m^3/sec.

A preliminary analysis of the topography of the land between the study area and the Islandmore Drain indicates that construction of a surface water conduit, by any route, would involve deep excavations, in excess of 3.5m at some locations. The optimum drainage route has been identified and is shown on Drawing No. 001.

The study area could be drained to the existing Kenny's Drain/ Islandmore Drain via an open drain, a closed culvert or a combination of the two. These options are discussed further below.

6.3.2 Islandmore Drain & Kenny's Drain

As noted above, it is proposed to terminate the flood alleviation drain at the existing Kenny's Drain (OPW Ref. F.799/1). Kenny's Drain is approximately 1km long and discharges to the Islandmore Drain (OPW Ref. C3/7), which in turn discharges to the Clare River approximately 1.2km downstream. The capacity of the Clare River is dealt with more comprehensively in the "Study to Identify Practical Measures to Address Flooding on the Clare River" report.

The capacity of Kenny's Drain and the Islandmore Drain have been calculated and the results are presented in Table 6.2. Section 1 is located at the head of the existing drain (Kenny's Drain), which is also the location of the discharge from the proposed flood alleviation drain. Drainage capacities have also been calculated between Section 1 and the point at which the drain crosses under a local road at Caherlea. These are labelled Sections 2 – 6 in Table 6.2, the locations of which are shown on Drawing No. 003 in Appendix B. Section 7 is located downstream of the road crossing and Section 8 is located upstream of the confluence with the Islandmore Drain (OPW Ref. C3/7). There is a 1m diameter culvert under the Caherlea Road, which is located between Sections 7 & 8.

Ref.	F.799/1								C3/7
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bed Width (m)	1.5	1.5	2	1.5	1.5	1.5	1.6	1.6	1
Side Slopes (1 in)	1.4	1.4	1.5	1	1	0.8	1.7	0.8	0.4
Depth (m)	0.7	1.3	1.5	1.4	1	1.3	1.2	1.3	2.7
A (m^2)	2.03	3.77	5.25	3.5	2.5	2.95	3.92	3.08	3.7
P (m)	4.81	5.47	7.00	5.60	5.11	5.47	5.60	5.72	6.76
R *(A/P)*	0.42	0.69	0.75	0.62	0.49	0.54	0.70	0.54	0.55
S_0	90	900	900	900	900	900	280	280	280
n	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Q (m^3/sec)	**4.01**	**3.27**	**4.82**	**2.84**	**1.73**	**2.17**	**6.16**	**4.06**	**4.93**

Table 6.2 Existing Capacities of OPW Drains

It is clear from Table 6.2 that the capacity of the drain needs to be increased upstream of the Caherlea Road, particularly at Section 5, prior to discharge of additional flow from the Carnmore East/ Cashla area. This will be addressed as part of the cleaning and limited regrading of the Islandmore and Kenny's Drains as recommended in the "Study to Identify Practical Measures to Address Flooding on the Clare River" report.

6.3.3 Open Conduit

An open drain would be cheaper to construct but would pose a greater safety risk to persons and animals along the route, particularly along deep sections, with risks including falls from height and drowning. This safety risk could be mitigated by separating the drain and surrounding land with a robust fence.

An open drain would also have the undesirable effect of draining the surrounding land during prolonged rainfall events. The majority of the land along the route of the drain would appear to be well draining, with the exception of land in the study area and land adjacent to approximately 300m at the North end of the drainage route. It is recommended that an open drain be lined so that it does not drain the land through which it passes.

There is also a greater risk of an open drain being interfered with or blocked, which would reduce its capacity and its efficacy to drain flood waters from the study area.

Manning's Equation is used to verify the capacity of an open drain, as follows;

$$Q = \frac{A*(A/P)^{2/3} x (S_0)^{1/2}}{n}$$

where;

Q= the flow capacity of the drain (m^3/sec or cumec)

A = the cross sectional area of flow (m^3)

P = the wetted perimeter of flow (m)

n = Manning's roughness coefficient (no units)

Generally, a trench with a width of 0.5m at its base, a minimum depth below ground of 1m, side slopes of 1 in 1 (i.e. 45°) and a minimum gradient of 1 in 500 will have a hydraulic capacity of 1.8 m^3/sec as follows;

Bed Width	0.5	m
Side Slopes	1 in 1	
Depth	1	m
A	1.5	m^2
P	2.74	m
S_0	1 in 500	
n	0.025	
Q	**1.80**	**m^3/sec**

At a depth of 1m, such a drain would be 2.5m wide on top, however it will become considerable wider along deeper sections (an additional 2 meters wide for every extra meter depth below 1m).

6.3.4 Closed Conduit

The alternative to an open drain is a closed one, in this case a 1050mm diameter concrete pipe, which laid at a gradient of 1 in 500 has a full bore capacity of approximately 1.2 m^3/sec. A 1050mm diameter pipe would be more expensive to construct than an open drain and would require inspection chambers at regular intervals (approximately every 150m). A closed conduit would eliminate many of the safety risks that would otherwise be associated with an open drain, however issues would remain at inspection chambers and the introduction of confined spaces would pose an additional risk for maintenance personnel.

A closed conduit, if constructed properly would reduce the effect that the conduit would have on the drainage of the surrounding land, when compared with an open drain. It would be necessary, however to 'stank' the pipe trench at intervals along the pipeline route, in order to prevent linear flow of water through the granular material surrounding the pipe.

6.3.4 Proposed Drainage Solution

It is proposed to construct a 1050mm diameter pipe from the study area along the route shown on Drawing No. 001, followed by an open drain for the final 370m upstream of the discharge to Kenny's Drain.

During detailed design stage it may be possible to identify additional sections where an open drain can be used in lieu of a closed conduit.

The following should be noted in relation to the proposal;

- land acquisition or a wayleave will be required along the route of the conduit,
- The piped section will require inspection chambers at 150m intervals,
- Fencing will be required along open sections of the drain to reduce any potential risk of injury to livestock or local residents.
- It will be necessary to cross the R339 in order to drain the flood waters in the vicinity of the houses which are at the greatest risk of flooding,
- The proposed drain will cross the Tuam Regional Water Supply Scheme watermain which is located in the R339 and supplies Athenry Town. A temporary diversion of the watermain will be required.
- 'Stanking' of the pipe trench will be required to stop it becoming a conduit for groundwater.
- An overflow structure will be required at the head of the pipeline route which will act as an overflow structure for the flood waters. The proposed weir level is 19.0m O.D. The size of this structure will be determined at detailed design stage, however it is envisaged that an adequately sized overflow structure will be able to covey the design flow of the flood alleviation drain under a depth of 250mm of flood water. This means that for a flood of the magnitude of that experienced in November 2009, the level of the flood waters will not exceed 19.25m O.D.
- The "Study to Identify Practical Measures to Address Flooding on the Clare River" report recommends that cleaning and limited regrading works be carried out on Kenny's Drain (OPW Ref. F.799/1) and the Islandmore Drain (OPW Ref. C3/7) to help alleviate flooding of the Caherlea/ Lisheenavalla. It is recommended that more substantial regrading works be carried out on Kenny's drain including replacing a 1m diameter culvert under the Caherlea Road with a 1.5m diameter culvert.

6.4. Viability of Measures

The flood risk management measures emerging from the initial viability screening process as summarised in Table 6.2 will now be assessed in further detail in the sections below.

The risk that will remain, following implementation of the flood alleviation measures proposed in this report, is calculated in Table 6.3, and this is subtracted from the damage caused by the 2009 Flood (see Table 5.3) in order to calculate the benefit of constructing the proposed flood alleviation drain.

Damage Caused in November 2009	Risk Remaining after construction of Flood Alleviation Drain	Benefit of Flood Alleviation Drain
€722,520	€110,080	€612,440

The cost benefit analysis that will be carried out for the construction of the proposed drain will compare the cost of this "benefit" to the cost of implementing the flood risk management measure. It should be noted that all costings are order of magnitude estimates at this outline design stage and have been prepared in the absence of site investigation. Costs also exclude VAT at this stage.

A benefit to cost ratio of 1.5 is desirable for a potential flood risk management measure to be considered economically viable.

6.4.1 Preliminary Assessment of Quantities, Costs and Benefits

The estimated cost of constructing a drain from a point immediately south of the R339, through fields, with a discharge to Kenny's Drain is €440,000.

Flood Event	Cost of Measures	Benefit	Benefit to Cost Ratio
November 2009	€440,000	€612,440	1.39

6.4.2 Assessment in relation to climate change

It is recommended that the sizing of the culverts at detailed design stage include an allowance of 20% additional flow to provide for potential climate change.

6.4.3 Future maintenance requirements

There will be an increased maintenance burden on the owner of the drain and piped section of the surface water outlet. Both the drain and the pipe will need to be inspected regularly and cleaned particularly after flood events.

6.4.4 Upstream/downstream flood risk

The proposed measure will reduce the upstream flood risk in the Carnmore East/ Cashla catchment. The provision of the measure will increase the flow in the Islandmore Drain at Caherlea & Lisheenavalla but this additional flow is expected to have minimal impact on the existing downstream flood risk provided the recommendations of the "Study to Identify Practical Measures to Address Flooding on the Clare River" report are implemented prior to construction of the proposed drain.

The discharge of additional flow of 1 m^3/sec to the Clare River is negligible, given the proposed increase of the capacity of the bridges at Crusheen and Claregalway to 220 m^3/sec.

6.5. Environmental Impact

The potential ecological impacts have been discussed in previous sections in relation to the viability of the proposed flood alleviation proposal.

It is recommended in the "Study to Identify Practical Measures to Address Flooding on the Clare River" report that all proposed channel and drainage works, which have been proposed in order to relieve flooding in the Clare River catchment, that potentially impact on the Lough Corrib Special Area of Conservation (cSAC), will need to be screened in relation to an Appropriate Assessment.

It is recommended that the works proposed in this report be included in the Appropriate Assessment Screening process particularly as the work is located upstream of the Lough Corrib Special Area of Conservation. If the outcome of this screening exercise cannot completely exclude the potential for impacts on the qualifying interests of the site, a full Habitats Directive Assessment will need to be carried out and the resultant Natura Impact Statement published. The assessment will also consider potential cumulative impacts to the cSAC when taken in combination with other works, developments, abstractions and inputs to the Clare catchment.

6.6. Outline Design of Proposed Measures

Drawing No.001 in Appendix B contains sketches of the proposed outline design of the recommended flood alleviation drain.

Ref.	Location	Analysis of Remaining Risk if Recommended Flood Alleviation Measures are Implemented						
		Flooded Residential Property	**Properties at Risk of Flooding**	**Flooded Commercial Property**	**Houses Cut Off by Flooding (per day)**	**Flooded Land (hA)**	**Traffic Diversions**	**Benefit (€)**
		25000	**10000**	**30000**	**160**	**400**	**20**	
1	Houses Flooded							**-**
2	Houses at Risk of Flooding		2					**20,000**
3	Business Premises at Risk of Flooding							**-**
4	Houses cut off by flooding (R339)				3			**480**
5	Houses cut off by flooding (L71116)				4			**640**
6	Houses cut off by flooding (L71119)				6			**960**
7	Houses cut off by flooding (L31013)				0			**-**
8	Flooding of R339, 660m						3000	**60,000**
9	Flooding of L31013, 80m							**-**
10	Flooding of L71116, 220m							**-**
11	Flooding of L71119, 110m							**-**
12	Land Flooded					70		**28,000**
	TOTAL (#)	**-**	**2**	**-**	**13**	**-**	**3,000**	
	TOTAL (€)	**-**	**20,000**	**-**	**2,080**	**28,000**	**60,000**	**110,080**

Table 6.3 Analysis of Remaining Risk

7. Conclusions and Recommendations

7.1. Conclusions

The flood event of November 2009 had severe consequences for residents and businesses in Carnmore East & Cashla and commuters on the R339 Regional Road. The rainfall that fell in the weeks and particularly just prior to the peak of the floods was statistically significant with 300% of normal rainfall falling in November 2009 and estimated return periods for the relevant rainfall events of 134 years for the 2 day rainfall, 293 years for the 4 day rainfall, 306 years for the 8 day rainfall, 272 years for the 16 day rainfall and 131 years for the 25 day rainfall ending on 26 November 2009.

The flood waters began to accumulate locally in Carnmore East and Cashla on the Tuesday 17th November 2009, with the first house flooded on the morning of Thursday 19th November. The last house flooded on Saturday 21st November and the flood waters continued to rise slowly until the following weekend, when they peaked at approximately 20.1m O.D., after which they receded slowly for two days before dissipating on Wednesday 2nd December 2009.

Overall, the flood lasted for a fortnight and flooded three houses and posed a flood risk to a further seven houses and two business premises. Traffic was also prevented from using the R339, which was over a metre deep in flood water, over the two week period and fourteen houses were cut out by the flood.

The estimated economic cost of the damages consequent to the flood of November 2009 amount to €722,500. The damages as a result of the closure of the R339 for a fortnight amount to approximately €490,000 alone.

Various potential flood risk management measures were investigated. All of the potential flood risk management measures were subjected to an initial viability assessment on technical, economic, environmental and social acceptability grounds. The flood risk management measure emerging from this process as potentially viable was then subjected to a further more detailed viability assessment which included a cost benefit analysis, assessment in relation to climate change, maintenance costs etc.

Any viable flood risk management measure must achieve a balance between lowering the flood level at Carnmore East/ Cashla so that no houses are flooded and roads remain passable and mitigating any potential downstream flood risk. The purpose of the flood alleviation measure is to reduce flooding from a similar sized flood event to November 2009.

It is proposed to construct a flood alleviation drain, consisting of a 1050mm diameter pipe and section of open drain from the a point immediately South of the R339 along the route shown on Drawing No. 001. The proposed drainage route is 1940m long.

The peak flood level in the River Clare at the bridge in Claregalway occurred on Sunday 22nd November, whereas the peak inflow to Flood No.2 at Carnmore East/ Cashla occurred two days earlier on Thursday 19th November. It is noted that the rate of inflow to the study area on the 22nd November was approximately one tenth of the peak inflow.

The following should be noted in relation to the proposal;

- It will be necessary to cross the R339 in order to drain the flood waters in the vicinity of the houses which are at the greatest risk of flooding. An overflow structure will be required at the head of the pipeline route. The proposed weir level of this overflow structure is 19.0m O.D. The size of this structure will be determined at detailed design stage, however it is envisaged that an adequately sized overflow structure will be able to covey the design flow of the flood alleviation drain under a depth of 250mm of flood water. This means that for a flood of the magnitude of that experienced in November 2009, the level of the flood waters will not exceed 19.25m O.D.
- The piped section will require inspection chambers at 150m intervals.
- Fencing will be required along open sections of the drain to reduce any potential risk of injury to livestock or local residents.
- 'Stanking' of the pipe trench will be required to stop it becoming a conduit for groundwater draining to Caherlea/ Lisheenavalla.
- Land acquisition or a wayleave will be required along the route of the conduit.
- The proposed drain will cross the Tuam Regional Water Supply Scheme watermain which is located in the R339 and supplies Athenry Town. A permanent diversion of the watermain will be required.
- The "Study to Identify Practical Measures to Address Flooding on the Clare River" report recommends that cleaning and limited regrading works be carried out on Kenny's Drain (OPW Ref. F.799/1) and the Islandmore Drain (OPW Ref. C3/7) to help alleviate flooding of the Caherlea/ Lisheenavalla. It is recommended that more substantial regrading works be carried out on Kenny's drain including replacing a 1m diameter culvert under the Caherlea Road with a 1.5m diameter culvert.

7.2. Recommendations

It is recommended that a flood alleviation drain be constructed between the study area and Kenny's Drain in order to eliminate the impact of flooding from an event of similar magnitude to that of November 2009. The proposed route for the drain is shown on Drawing No. 001. It is also proposed that modifications be made to the Islandmore Drain beyond those proposed in the "Study to Identify Practical Measures to Address Flooding on the Clare River" report, including replacing a culvert under the Caherlea Road.

The cost of the constructing the proposed drain and the benefits accruing from the flood alleviation are as follows;

Flood Event	Cost of Measures	Benefit	Benefit to Cost Ratio
November 2009	€440,000	€612,440	1.39

It is recommended that the construction of such a drain not take place until the recommendations of the "Study to Identify Practical Measures to Address Flooding on the Clare River" report are implemented in full, particularly the measures proposed in the channel of the River Clare and on the Islandmore Drain at Caherlea & Lisheenavalla.

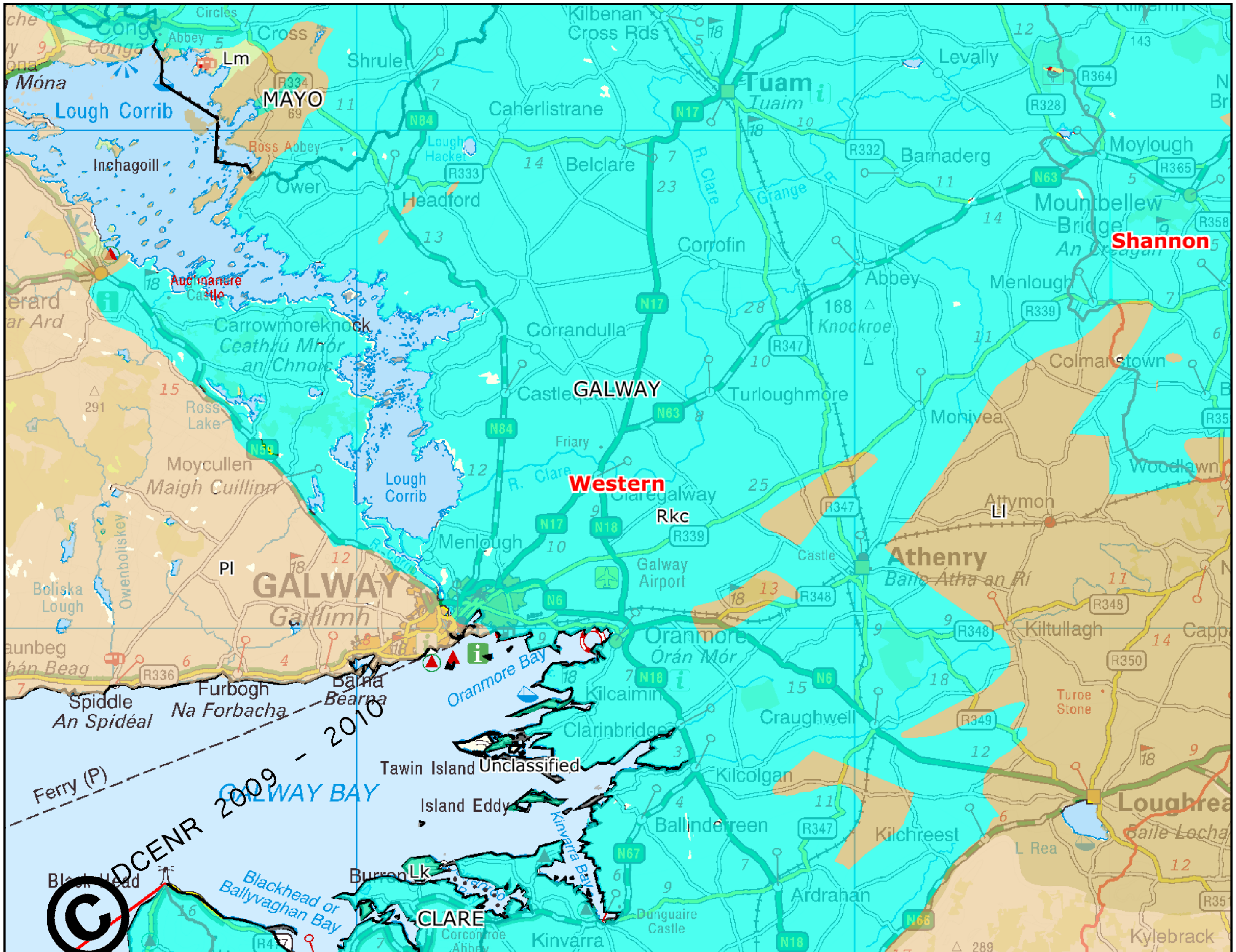
It is recommended that the flood alleviation measures proposed in this report be incorporated into the planning process for the Flood Alleviation Works currently proposed for the Clare River. This will include liaison with the National Parks and Wildlife Service and Inland Fisheries Ireland (IFI), and with Galway County Council in relation to the works on the R339 regional road and the Tuam Regional Water Supply Scheme trunk watermain, which are along the route of the proposed drain.

The proposed measures should proceed to detailed design as soon as possible.

Appendix A

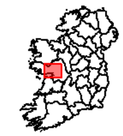
Extracts from GSI

Aquifer Map



0 8 16 24 km.

Map center: 138138, 232452



Legend

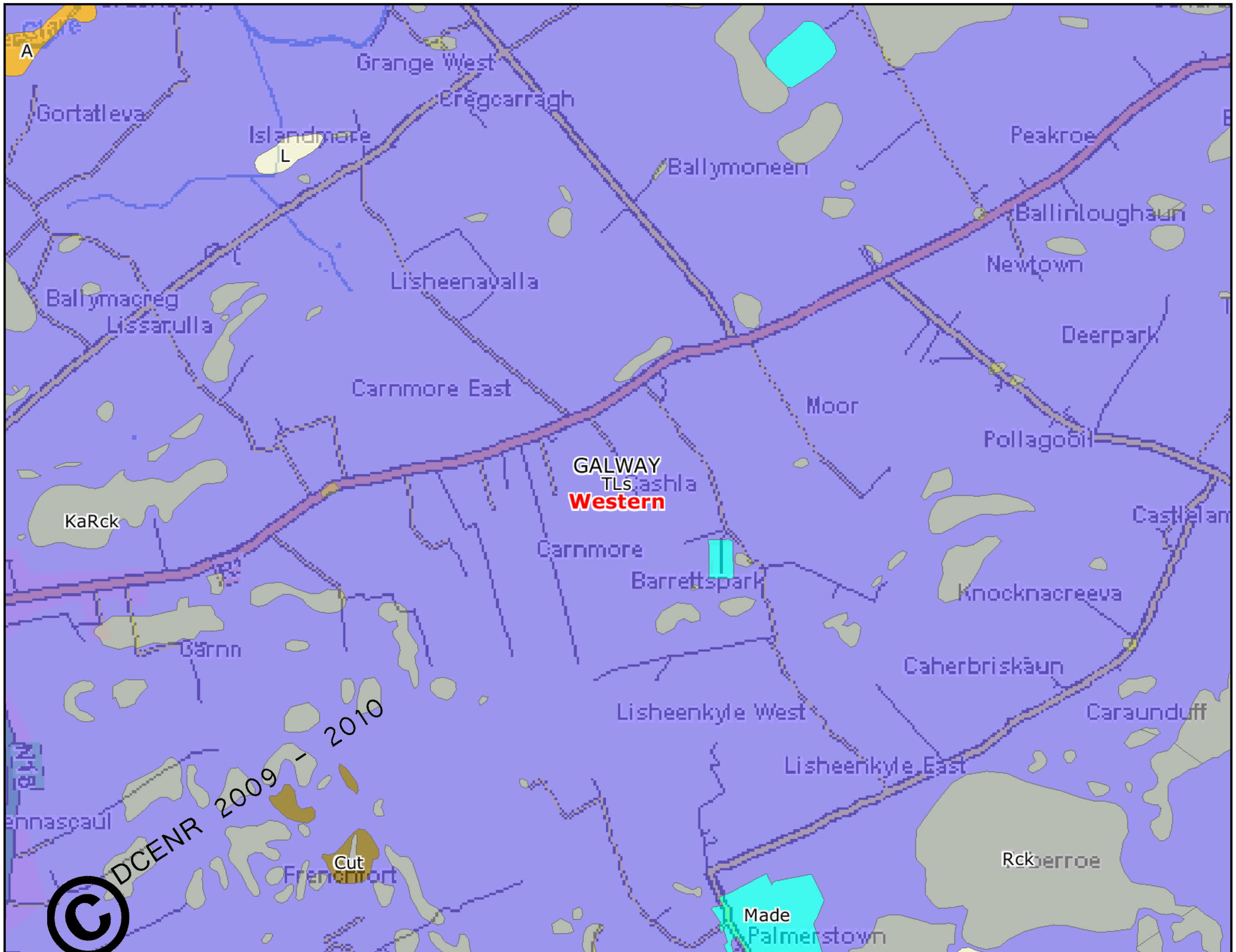
National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
- Lm - Locally Important Aquifer - Bedrock which is Generally Moderately Productive
- Lk - Locally Important Aquifer - Karstified
- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified
- RBD Boundaries
- County Boundaries

Scale: 1:319,356

Snapshot Date: 10-Aug-2010

soils



0 1100 2200 3300 m.

Map center: 142482, 229486

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands
- RBD Boundaries
- County Boundaries

Scale: 1:41,897

Snapshot Date: 10-Aug-2010

Appendix B

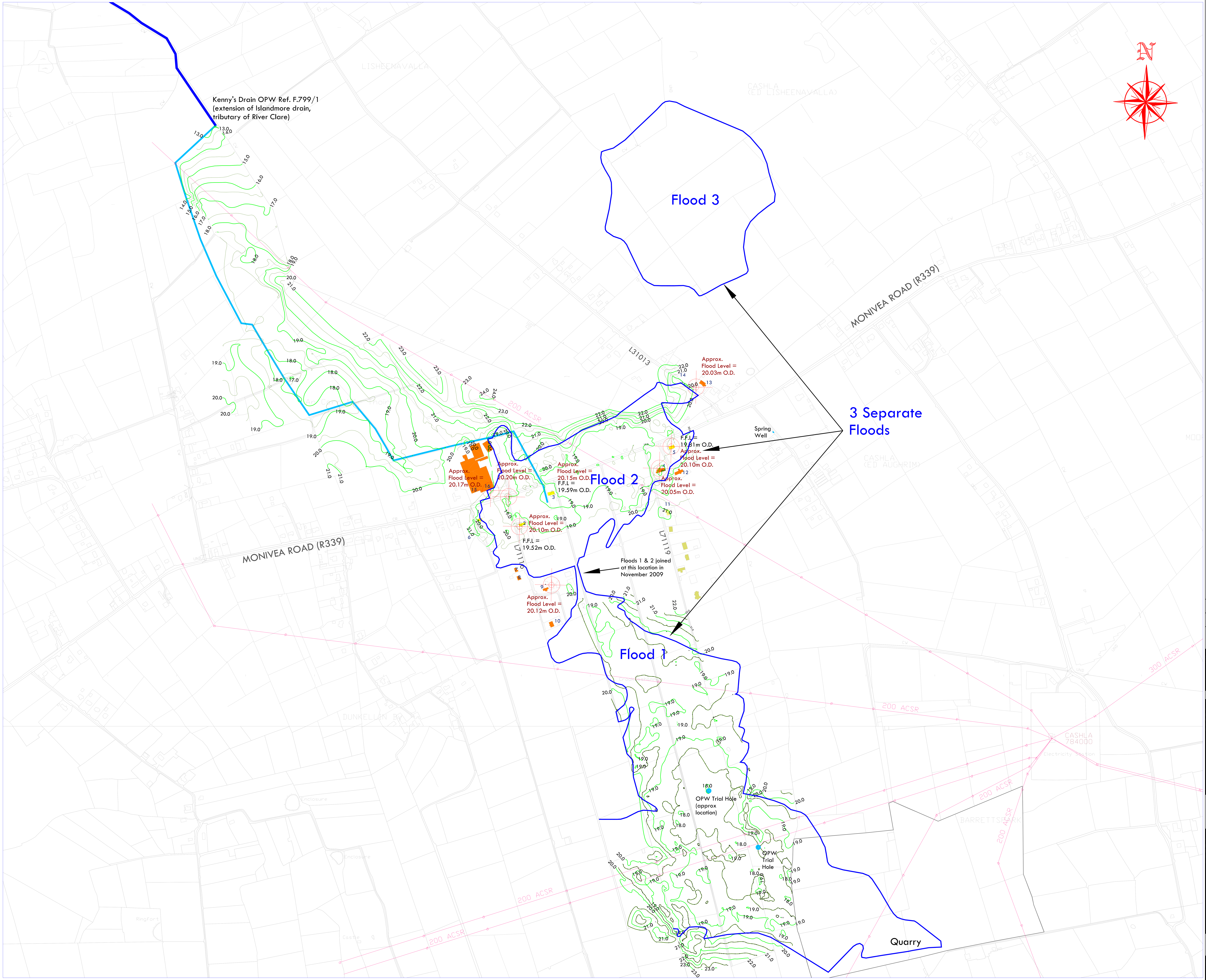
Drawings

Drawing No. 001 Layout Plan of Study Area

Drawing No. 002 Layout Plan & Longitudinal Section of R339 & L31013

Drawing No. 003 Layout Plan & Longitudinal Section of Islandmore Drain

Drawing No. 004 Layout Plan & Longitudinal Section Proposed Flood Alleviation Drain



NOTES

LEGEND

Flood Extents (Not Peak Flood)
(Aerial Photography, circa 30th November 2009)

Topographical Contours

Proposed Flood Alleviation Drain

Existing Watercourse

Spot Height/ Flood Level — Approx. Flood Level = 20.12m O.D.

High Voltage Power Lines — 200 ACSR

Regional/ Local Road — R339/ L31013

Premises No. (as per Table below) — 12

Premises/Dwelling Flooded in November 2009

Premises/ Dwelling at Risk of Flooding in November 2009

Premises/ Dwelling cut off by November 2009 Flood

HOUSES

No.	Owner	F.F.L. (m O.D.)	Flooded	Reported Flood Depth
1	Padraig Conneely	19.64	Yes	15 inches
2	Michael Flaherty	19.524	Yes	22½ inches
3	Danny Potter	19.59	Yes	22 inches
4	Martin Joe Feeney	20.254	No	
5	Ned Keogh	19.814	Yes	11 inches
6	Mary Conneely	21.53	No	
7	Peadar Conneely	20.65	No	
8	Marie Conneely	~20.65	No	
9	Gerry Hanley	20.10	No	
10	Peadar Conneely	-	No	
11	Martin Joe Feeney	21.17	No	
12	John Greaney	20.30	No	
13	Thomas Collins	20.54	No	
14	Mr Collins	20.96	No	

BUSINESS PREMISES

No.	Name	F.F.L. (m O.D.)	Flooded
15	Greaney Glass	~20.15	No
16	Newell Roofing	~20.15	No

NOTES

1. Levels are in metres to Malin Head Ordnance Datum (m. O.D.), unless stated otherwise.
2. The boundary line on the map showing the November 2009 Flood Extents is based on aerial photographs taken on 19th November 2009 and does not reflect the peak flood levels which were recorded later in the month.

REV	DATE	DRN	DESCRIPTION	CHK	APD

REVISIONS

DRAWING STATUS

- ☐ PRELIMINARY ☐ CONTRACT ☐ TENDER
- ☐ PLANNING ☐ CONSTRUCTION ☐ FOR APPROVAL
- ☒ FOR YOUR INFORMATION ☐ AS CONSTRUCTED ☐ DRAFT

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue
Taylor's Hill, Galway
Tel:(091)587116 Fax:(091)587110
Email: rhc@ryanhanley.ie
Web: www.ryanhanley.ie
DUBLIN OFFICE: Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford, Dublin18.

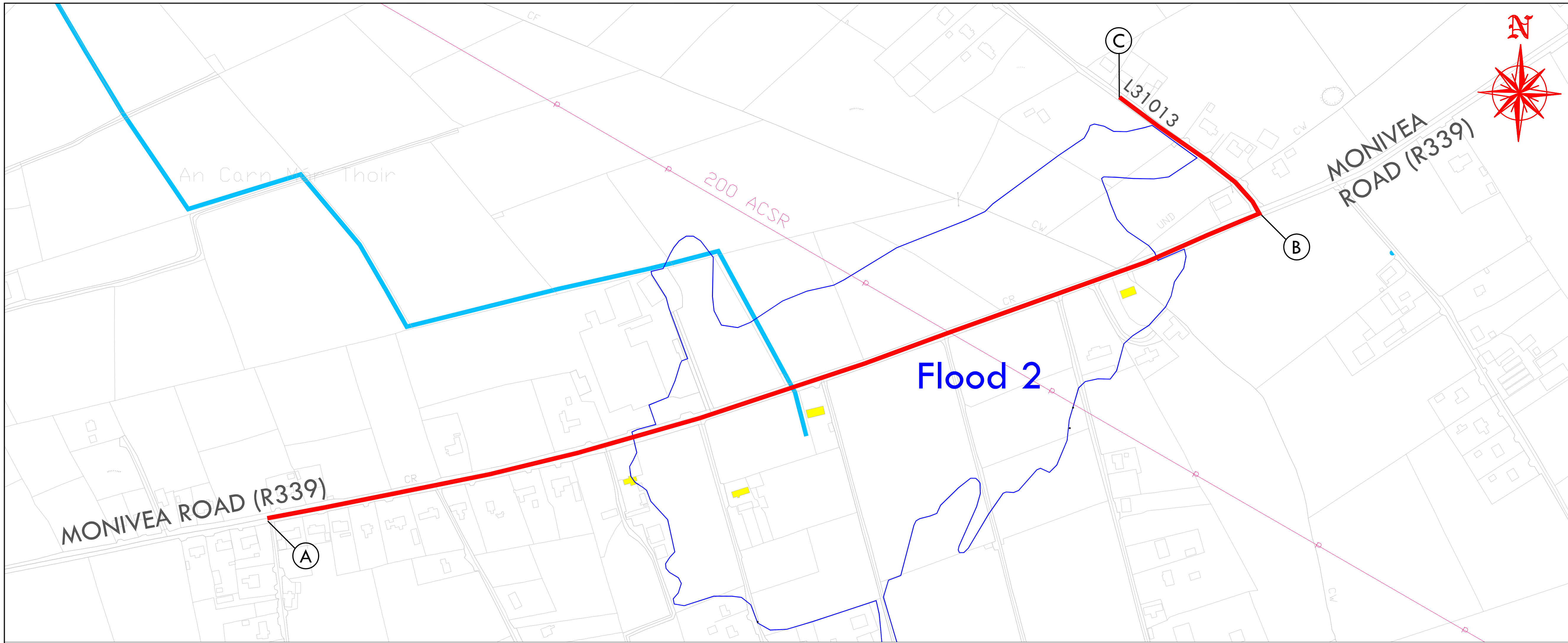
CLIENT
Office of Public Works

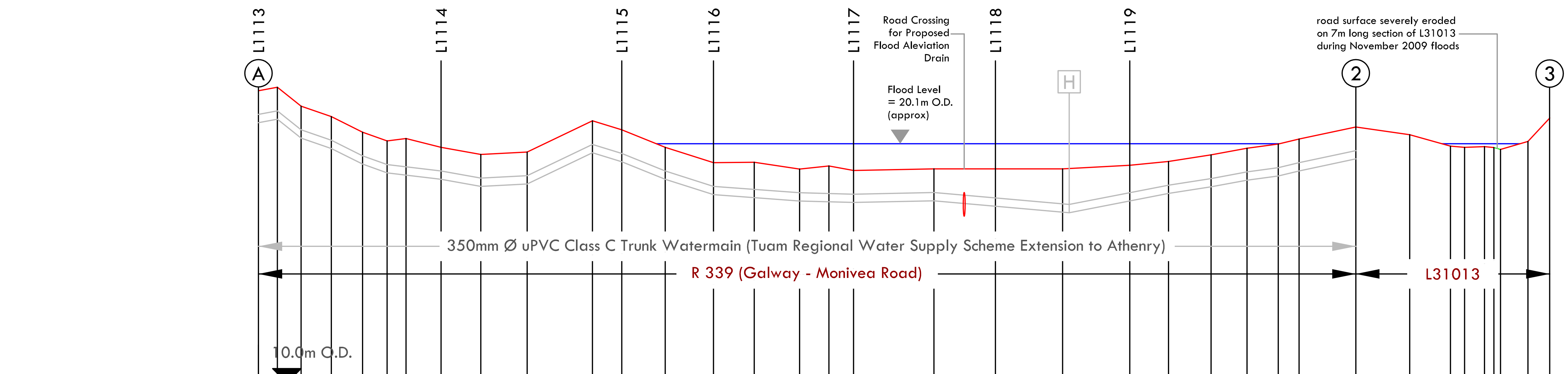
PROJECT
Carnmore Cashla Flooding Report

TITLE
Layout Plan of Survey Area

SCALE @ A1	DATE	DRAWN	CHECKED	APPROVED
1:5,000	AUG 2010	J.R.	C.L.	M.J.

JOB No.	DRAWING No.	REV.
2138	001	





Road Level (m.o.d.)	Chainage (m.)
22.34	0
22.49	20
21.69	45
21.25	77
20.59	110
20.22	136
20.32	156
19.95	193
19.65	235
19.75	284
21.07	353
20.69	384
19.95	430
19.30	481
19.32	524
19.03	572
19.16	603
18.97	629
19.04	714
19.04	779
19.04	850
19.19	921
19.35	962
19.63	1007
19.91	1045
20.09	1078
20.30	1100
20.81	1160
20.48	1217
20.00	1260
19.95	1275
19.98	1296
19.86	1313
20.20	1342
21.19	1365

Drawn using LONGSEC – Copyright © CCS

NOTES

LEGEND

- Flood Extents (not peak flood) (Aerial Photography, 30th November 2009)
- Propsosed Flood Alleviation Drain Existing Watercourse
- High Voltage Power Lines — 200 ACSR
- Regional/ Local Road — R339/ L31013
- Houses Flooded in Nov '09

REV	DATE	DRN	DESCRIPTION	CHK	APD

REVISIONS

DRAWING STATUS

- ☐ PRELIMINARY
- ☐ CONTRACT
- ☐ TENDER
- ☐ PLANNING
- ☐ CONSTRUCTION
- ☐ FOR APPROVAL
- ☒ FOR YOUR INFORMATION
- ☐ AS CONSTRUCTED
- ☐ DRAFT

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue
Taylor's Hill, Galway
Tel:(091)587116 Fax:(091)587110
Email: rhc@ryanhanley.ie
Web: www.ryanhanley.ie
DUBLIN OFFICE: Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford, Dublin18.

CLIENT
Office of Public Works

PROJECT
Carnmore Cashla Flooding Report

TITLE
Layout Plan and Longitudinal Section of R339 & L31013

SCALE @ A3	DATE	DRAWN	CHECKED	APPROVED
Horz: 1:1000 Vert: 1:200	AUG 2010	J.R.	C.L.	M.J.

JOB No.	DRAWING No.	REV.
2138	002	

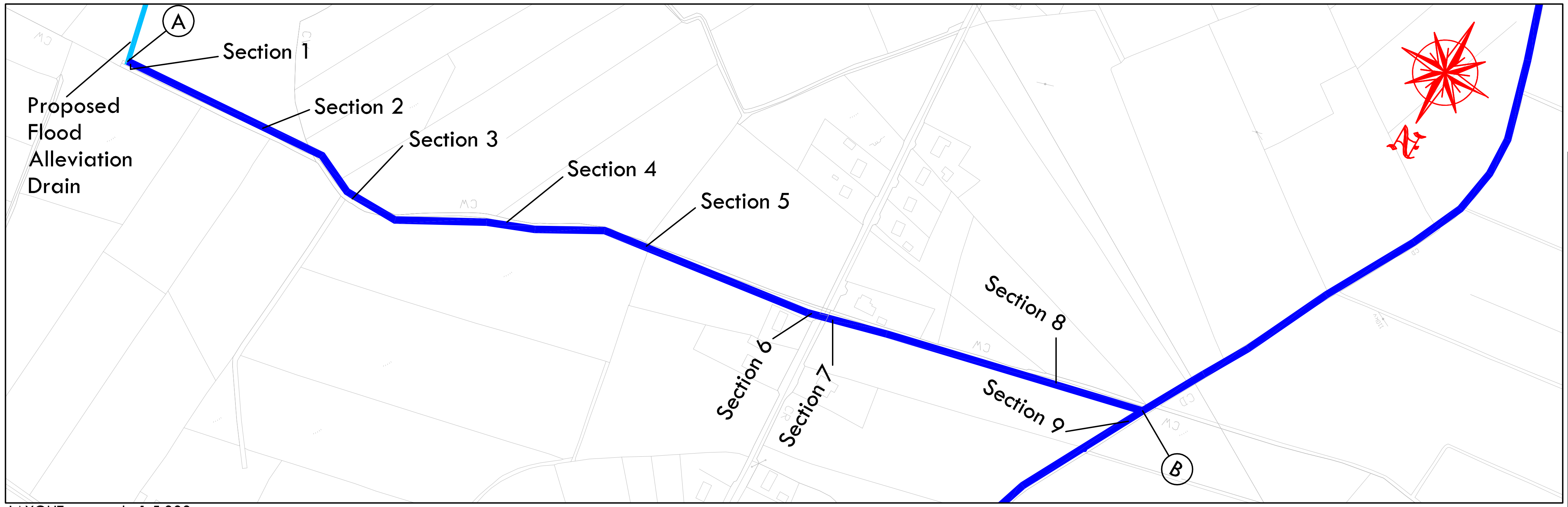
NOTES

LEGEND

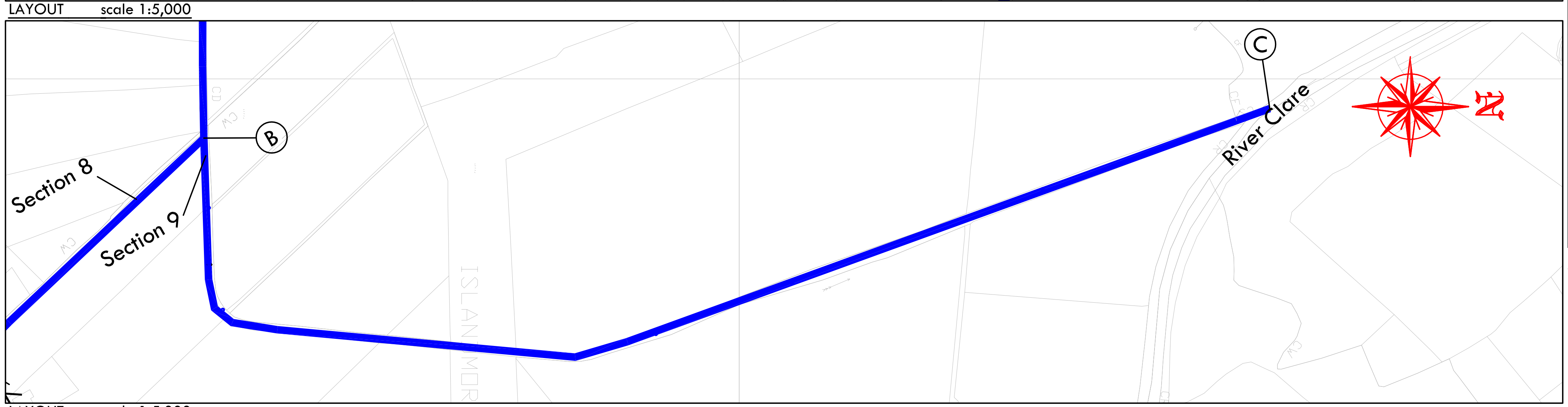
Proposed Flood Alleviation Drain

Existing Watercourse

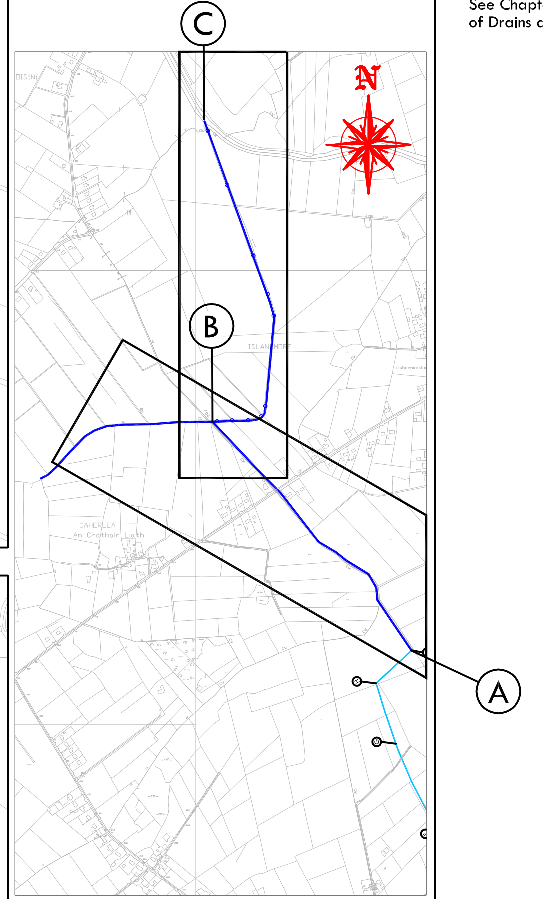
See Chapter 6 of Report for Capacities of Drains at Sections shown on Layout Plans.



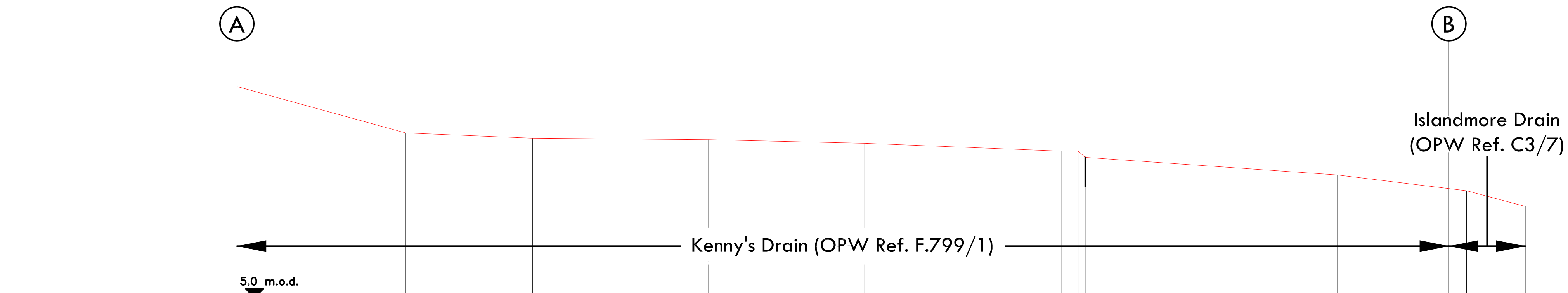
LAYOUT scale 1:5,000



LAYOUT scale 1:5,000

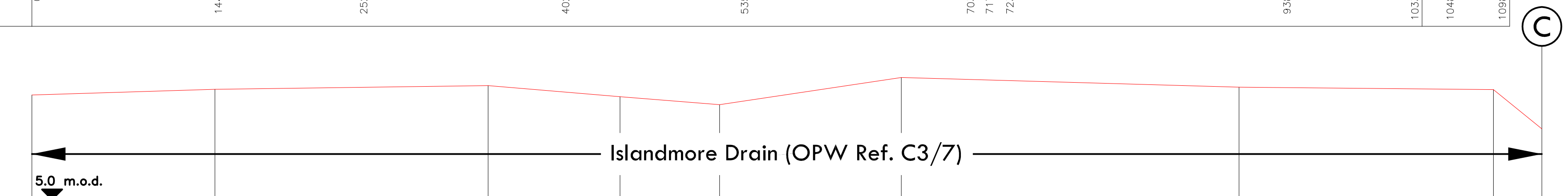


KEYPLAN scale 1:25,000



Existing Invert Level (m.o.d.)	12.19	10.61	10.43	10.38	10.26	9.99	9.99	9.78	9.18		8.64	8.11
Chainage (m.)	0	144	252	402	535	703	717	723	938	1033	1048	1098

Drawn using LONGSEC – Copyright ©



Existing Invert Level (m.o.d.)	8.11	8.28	8.39	8.06	7.82	8.63	8.34	8.27	7.10
Chainage (m.)	1098	1234	1437	1535	1609	1744	1995	2184	2220

Drawn using LONGSEC – Copyright ©

REV	DATE	DRN	DESCRIPTION	CHK	APD

REVISIONS

DRAWING STATUS

- ☐ PRELIMINARY
- ☐ CONTRACT
- ☐ TENDER
- ☐ PLANNING
- ☐ CONSTRUCTION
- ☐ FOR APPROVAL
- ☒ FOR YOUR INFORMATION
- ☐ AS CONSTRUCTED
- ☐ DRAFT

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue
Taylor's Hill, Galway
Tel:(091)587116 Fax:(091)587110
Email: rhc@ryanhanley.ie
Web: www.ryanhanley.ie
DUBLIN OFFICE: Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford, Dublin18.

CLIENT

Office of Public Works

PROJECT

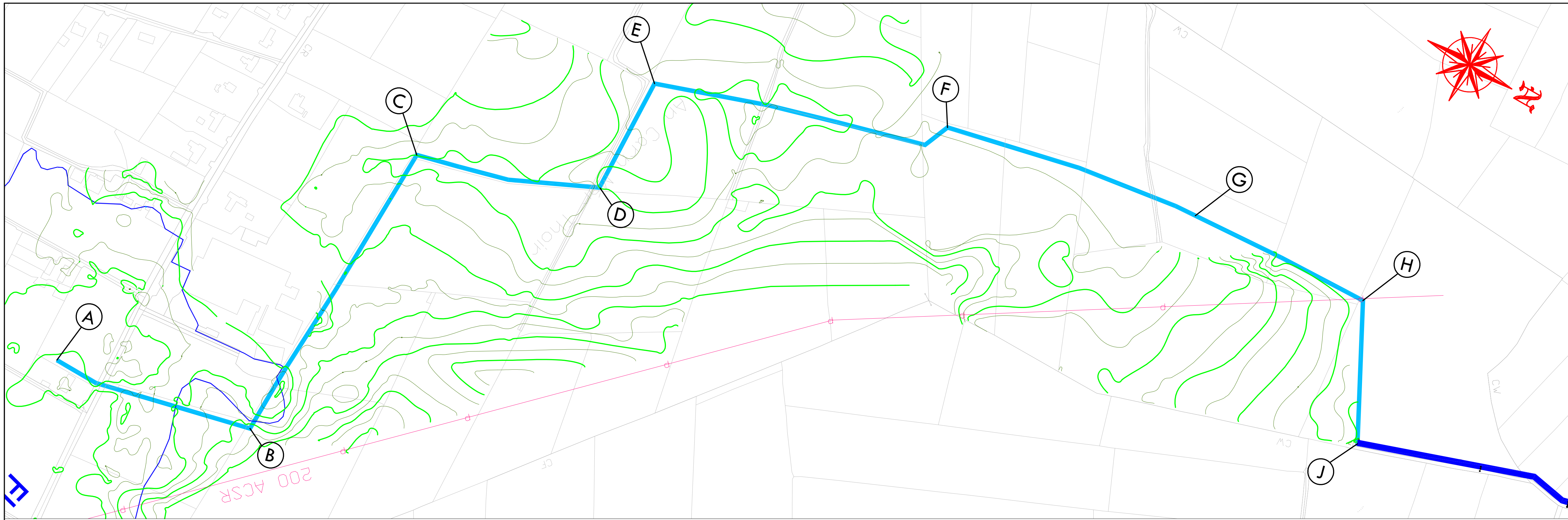
Carnmore Cashla Flooding Report

TITLE

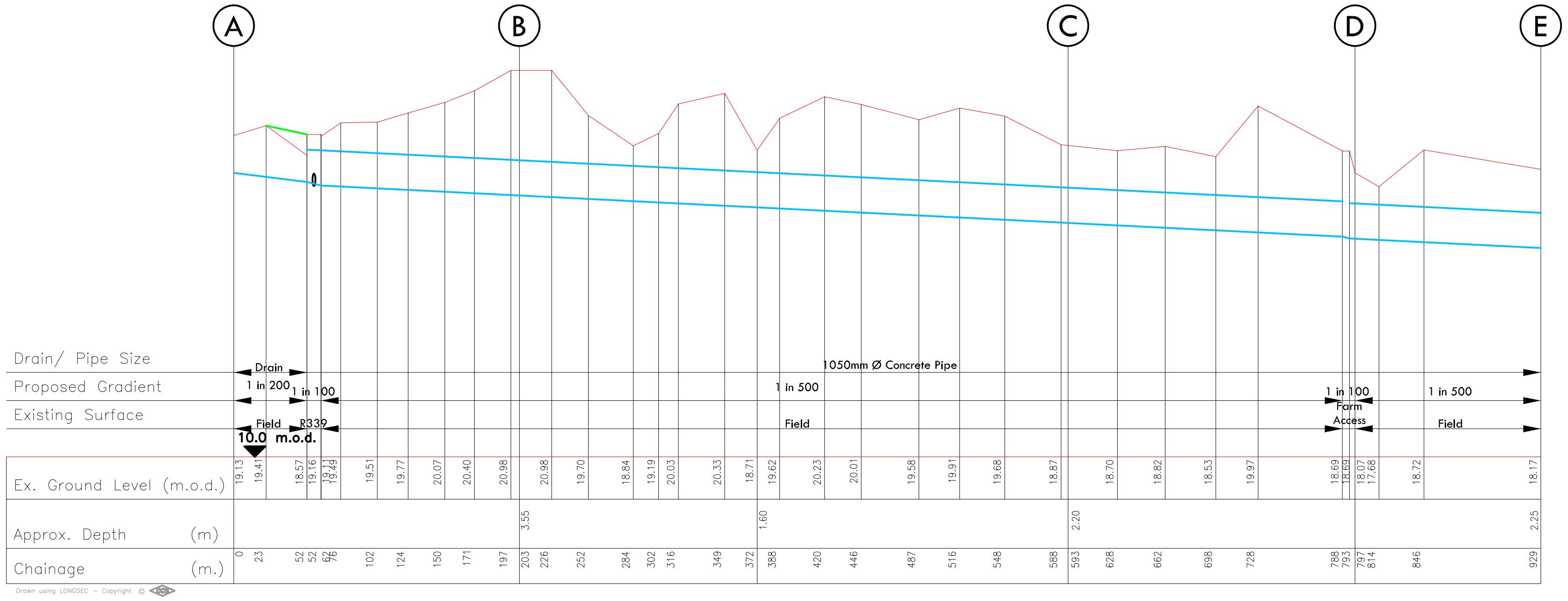
Layout Plan and Longitudinal Section of Islandmore Drain

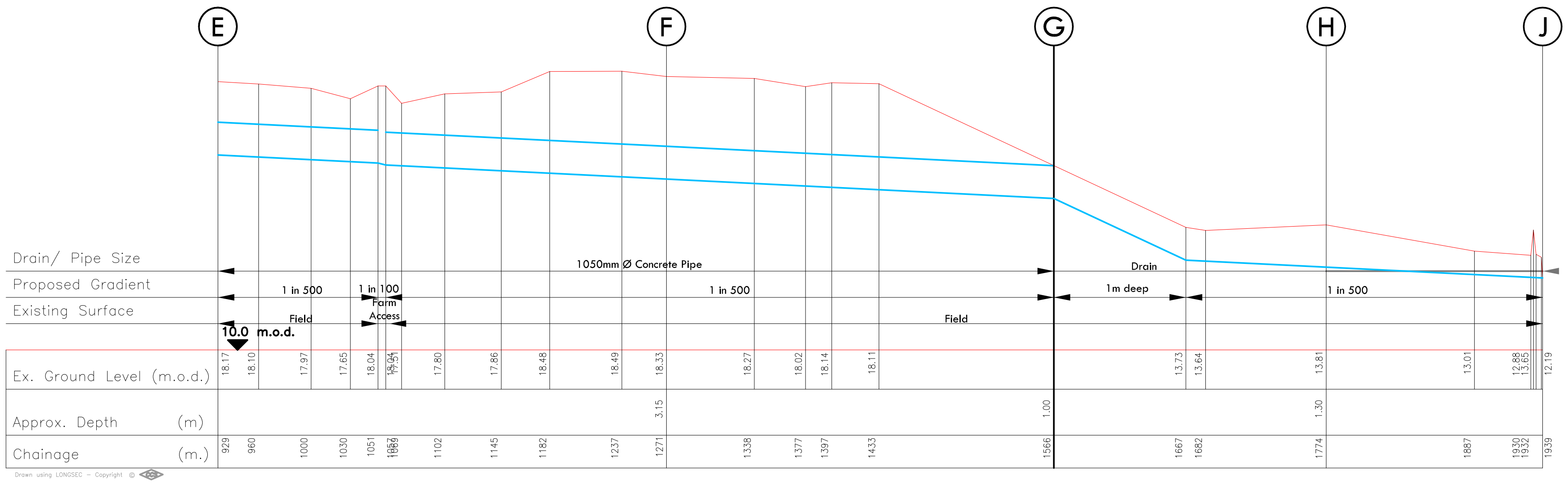
SCALE @ A3	DATE	DRAWN	CHECKED	APPROVED
Horz: 1:5000 Vert: 1:1000	AUG 2010	J.R.	C.L.	M.J.

JOB No.	DRAWING No.	REV.
2140	003	



LAYOUT scale 1:5,000





LEGEND

Flood Extents (not peak flood) (Aerial Photography, 30th November 2009)	
Proposed Flood Alleviation Drain	
Existing Watercourse	
High Voltage Power Lines	200 ACSR
Regional/ Local Road	R339/ L31013

NOTES

1) Pipe Trench to be 'stanked'
2) Access Chambers to be constructed every 150m, at bends and changes in gradient
3) Overflow Structure to be constructed at Node A with an overflow level of 19.0m O.D.
4) Outfall structure to be constructed at end of piped section of drain
5) During detailed design stage it may be possible to identify additional section where an open drain can be used in lieu of a closed conduit.

REV	DATE	DRN	DESCRIPTION	CHK	APD
A	NOV 10	RK	NOTE 5 ADDED	JR	CL

REVISIONS

DRAWING STATUS

- ☐ PRELIMINARY ☐ CONTRACT ☐ TENDER
- ☐ PLANNING ☐ CONSTRUCTION ☐ FOR APPROVAL
- ☒ FOR YOUR INFORMATION ☐ AS CONSTRUCTED ☐ DRAFT

RYAN HANLEY
CONSULTING ENGINEERS
Sherwood House, Sherwood Avenue
Taylor's Hill, Galway
Tel:(091)587116 Fax:(091)587110
Email: rhc@ryanhanley.ie
Web: www.ryanhanley.ie
DUBLIN OFFICE: Suite D4, The Cubes Offices, Beacon South Quarter, Sandyford, Dublin18.

CLIENT
Office of Public Works

PROJECT
Carnmore Cashla Flooding Report

TITLE
Layout Plan and Longitudinal Section of Proposed Drain

SCALE @ A3	DATE	DRAWN	CHECKED	APPROVED
Horz: 1:5000 Vert: 1:1,000	AUG 2010	J.R.	C.L.	M.J.

JOB No.	DRAWING No.	REV.
2138	004	A