

Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study

Technical Assessment: River Shannon Level Operation Review



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Abbreviations and Glossary

General

Callows	The ‘callows’ are the floodable areas adjacent to the River Shannon – there are large callow areas between Portumna and Lough Ree and along the rivers Suck and Little Brosna, and there are smaller but significant areas north of Lough Ree up to Lough Allen. Although heavily modified by hundreds of years of traditional agricultural and rural practices, the areas are cited as among the last substantial floodplains in Western Europe that are not embanked and can flood freely. The callows are a significant habitat in terms of birds and wildlife. The river is of international environmental importance - long reaches of the River Shannon, the adjacent callows and the lakes are candidate designations, or are designated under the Habitats and Birds Directives.	
CFRAM Study	Catchment-based Flood Risk Assessment and Management Study	
EPA	Environmental Protection Agency	In Ireland, the EPA protects the environment through its licensing, enforcement and monitoring activities.
ESB	Electricity Supply Board	The ESB has a mandate to generate electricity, and its responsibilities on the River Shannon relate to the hydro-electric scheme at Ardnacrusha and regulation of the three main lakes.
IFA	Irish Farmers Association	The IFA represents many farmers in the Shannon catchment.
IPC	Integrated Pollution Control	The EPA has been licensing certain large-scale industrial and agriculture activities since 1994. Originally the licensing system was known as Integrated Pollution Control (IPC) licensing, governed by the Environmental Protection Agency Act, 1992. The Act was amended in 2003 by the Protection of the Environment Act, 2003 which gave effect to the Integrated Pollution Prevention Control (IPPC) Directive.
mOD	metres above Ordnance Datum	See Section 1.4 for background to Ordnance Datum (Poolbeg) used in this report.
NPWS	National Parks and Wildlife Service	NPWS prepares and manages policy in relation to the natural environment, and has national and international responsibilities.

OPW	The Office of Public Works	The OPW are responsible for flood risk management in Ireland.
SEA	Strategic Environmental Assessment	
WI	Waterways Ireland	WI is the North/South Implementation Body for the inland navigable waterways system. WI took over the inland navigation role previously managed by Dúchas Waterways and prior to that the OPW.

Definition of Seasonal Periods

Flood Period	Defined in ESB Regulation 1.2.	Applies when conditions are such that spilling as distinct from drawing water from storage may soon be necessary. For Lough Derg applies when the Killaloe Pier Head level is above 33.56 mOD as confirmed in Regulation 1.5.5.2.
Summer Period	1 April to mid October (taken in this report as 15 October)	Defined in ESB Regulation 1.5.3.2 (specifically in relation to water levels downstream of Athlone Weir)
Early Summer	Defined in this report as 1 April to 15 August	Period when ESB endeavours to restrict the drawdown of Lough Ree to a Minimum Normal Operating level of 37.49 mOD
Late Summer	Defined in this report as 16 August to 30 September	Period when ESB endeavours to restrict the drawdown of Lough Ree to a Minimum Normal Operating level of 37.19 mOD.
Winter	Mid October to 1 April (taken in this report as 16 October – 31 March)	Defined in ESB Regulation 1.5.3.2 (specifically in relation to water levels downstream of Athlone Weir)

Definition of Water Levels used in this Report

Exceptional Reservoir Level	Defined in ESB Regulation 1.4.2 in for Loughs Allen and Derg and related to dam safety issues of earthen embankments
Maximum Normal Operating Level (ESB Regulations & Guidelines document, Definitions)	Highest level allowable in the operation of the reservoir under normal operating conditions. It can only be exceeded under special flood instructions.
Minimum Navigation Level (applies to Lough Ree only) (ESB Regulations & Guidelines document, Table 1.2 and Section 2.7.3.4)	Navigation between Athlone and Tarmonbarry must be prohibited under the Electricity (Supply) Act 1927 when the water level in Lough Ree falls below 36.88 mOD.

Minimum Normal Operating Level (ESB Regulations & Guidelines document, Definitions)	Lowest level allowable in the reservoir under normal operating conditions. For Lough Derg it is the level above which maximum hydropower output from start-up is possible without constraint.
Ordinary Summer Level (OSL) - sometimes referred to as Normal Summer Level in other documents	The water level of each reach of the Shannon as retained by the various water level control structures. With low summer flows the water level gradient is generally assumed to be negligible. The OSL downstream of one structure is generally the same as the OSL on the upstream side of the next structure.
Sill Level	Traditionally water levels upstream and downstream of the Shannon Navigation Locks have been measured relative to the Upper Sill and Lower Sill levels respectively – i.e. the physical level of the masonry construction of the lock, above which a minimum water depth is required to permit safe navigation by vessels of a given draft.
“Target” level	<p>Target levels for the drawing down of Lough Ree during non-Flood periods. Currently defined in ESB Guideline 2.7.3.2 to optimise storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years.</p> <p>Also used for operation of the sluices at Meelick Weir where the “target” is to maintain Ordinary Summer Level at Banagher.</p>
“Trigger” level	<p>Levels used to control day-to-day operations. At Athlone Weir the key downstream “trigger” levels are defined in ESB Regulation 1.5.3.2 and relate to the risk of waterlogging and flooding in the callows.</p> <p>At Meelick Weir the “trigger” levels used by WI relate to the +/- 0.05m variation about the Ordinary Summer Level at Banagher of 35.36 mOD (which applies throughout the reach from Athlone to Meelick Weir/Victoria Lock).</p>

Executive Summary

The River Shannon Level Operation Review Report assesses the operating regulations and procedures of the control structures along the river Shannon with the purpose of identifying immediate, short term potential improvements with respect to flood risk management.

The findings and recommendations of this report have been reached without the benefit of the detailed hydrological analysis and hydraulic modelling which is being carried out between 2012 and 2014, as part of the wider Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study. These findings and recommendations are therefore interim and may be subject to refinement once the more detailed technical analysis has been undertaken.

Initial consultation meetings were held with ESB and Waterways Ireland in March 2011 and extensive hydrometric datasets were subsequently made available for use in the study. A meeting was held with representatives of the Irish Farmers Association in Athlone in April 2011. A literature review was also undertaken covering almost two centuries of development of the Shannon and a succession of reports on flood risk management.

Following the literature review, initial data analysis and consultation, it was concluded that the operation of the control structures at Lough Allen (Bellantra Sluices), Parteen Weir, Ardnacrusha Power Station and the navigation weirs upstream of Lough Ree does not have a significant impact on the occurrence, degree or duration of flooding. The area of greatest concern relating to the operation of control structures on flood risk management issues is the callows area between Athlone Weir and the water level control structures in the vicinity of Meelick and Victoria Lock. This report therefore focuses on this area.

The callows area has an international environmental designation and comprises semi-natural grassland, which is managed by individual landowners. The Irish Farmers Association (IFA) represents the interests of most of these landowners and generally they accept that farmland within the callows is liable to flooding in the winter by virtue of the fact that it is natural floodplain. It is summer flooding and any flooding potentially exacerbated by the operation of control structures on the River Shannon that is the primary cause for concern of the IFA. Particular concern has been expressed over late summer (i.e. 16 August to 30 September) flooding in the callows which can have a major impact on damage to the crop before it is harvested.

Why has late summer flooding increased in recent years?

Our analysis of existing water level records confirms the perception that late summer flooding in the last decade has been significantly greater than over the previous four decades or so. However, it is worth bearing in mind that the incidence of late summer flooding in the two decades 1942-1961 was in fact higher than the last decade (period 2002-2010). Our examination of August and September rainfall records shows that this pattern is likely to be a direct consequence of climatic variability. There is no evidence from our analysis that the change in the operating procedures of the sluices at the Athlone weir, which occurred in 1972, and which affects drawing down the storage in Lough Ree, has had a direct impact on the frequency of late summer flooding in the callows.

What causes flooding in the callows?

Downstream inflows, primarily from the Suck, have a significant influence on the onset of flooding in the callows. Observed flow hydrographs for the Suck and the Brosna confirm that, during the rising limb of a flood, the proportion of the total gauged inflow to the callows from the Suck and the Brosna rises to over 40%, compared with a typical figure of 20-25% in non-flood periods. In August 2008 this proportion rose above 60%.

Examination of the Waterways Ireland records of sluice openings at Meelick Weir and the New Cut and comparison with level records at Athlone over the summers of 2007 to 2010 confirms that the periods when all 30 sluices were fully opened coincides almost exactly with periods when the downstream level at Athlone exceeds the 36.12 mOD “trigger” level for potential waterlogging of the callows. The records also indicate that, where they were in place before the event, the weir boards were all removed in a timely manner.

Our analysis of 5 recent summer flood events shows that the period from when all sluices at Meelick and the New Cut were fully opened and all weir boards removed to the time when peak water levels in the callows were reached varied from a minimum of 10 days in July 2009 to as many as 38 days during the double peak event in August-September 2008. Hence we confirm the conclusions of previous reports that sluice operations at Meelick and the New Cut have no adverse impact on flooding in the callows, provided Waterways Ireland operate the sluices and remove the weir boards in accordance with the normal procedures.

It has been suggested that storage effects in the river between Athlone and Meelick affects the onset or extent of flooding within the reach; as does the effects of the apparent intermediate control at Madden's Island (also known as Counsellor's Ford), near Esker downstream of Banagher.

Examination of such storage effects and other local controls between Athlone and Meelick would require the use of a suitable hydraulic model which will not be available through the CFRAM Study until 2013, at the earliest. However, from our analyses for this Report we are satisfied that, whilst such effects may be of some significance at low flows, the likelihood of them having any impact on either the eventual flood peak level in the callows, or the duration of the flood, is very small.

Could recent summer floods have been managed differently?

The summers of 2008 and 2009 were particularly wet. In the absence of any reliable long term forecasting and to avoid potentially exacerbating flooding in the callows downstream of Athlone Weir, ESB exercised its discretion under the Regulations and Guidelines for the control of the River Shannon, taking account of water levels, flows, recent rainfall, Met Eireann weather forecasts and ESB's forecasting model, not to open the sluices at Athlone Weir.

We carried out a theoretical analysis with the benefit of perfect hindsight, assuming that the level in Lough Ree was drawn down as far as possible towards the minimum level in the bands outlined in ESB Guidelines. Our analysis ignored the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows at the onset of waterlogging. Our studies showed that, in theory, Lough Ree levels could have been drawn down somewhat prior to the summer floods in 2008 and 2009. Other than in very limited areas, such additional draw down would only have delayed the onset of flooding by less than one day, with no reduction in either the extent of flooding, or the total duration of flooding.

To avoid exceeding a downstream level of 36.12 mOD (the summer period waterlogging constraint), discretionary control of the level of Lough Ree by opening of the sluices at Athlone can generally only be achieved when the outflow from Lough Ree drops below about 70-80 m³/s, corresponding to a level of about 37.9 mOD. Above this level therefore Lough Ree effectively acts as an unregulated lake. Below this level the scope for regulation is severely constrained by both the naturally high lake levels in relatively wet summers and the ESB guidelines for limiting drawdown to ensure adequate water levels towards the end of dry summers.

The starting level of Lough Ree has no impact on flood extents during the peak of the event. The increased storage due to lower levels would be very small in comparison to the volume of the hydrograph leading up to the subsequent flood peak. Moreover, if the level of Lough Ree were to be drawn down further, subsequent outflows on the rising flood would be reduced due to the fixed hydraulic characteristics of Athlone Weir. Hence more of the volume of the rising flood would be retained in Lough Ree, thus effectively “losing” the increased storage before the peak of the event is reached.

As a result of our analysis it can be concluded that whether sluices at Athlone are opened in advance of a flood or not, it only has a marginal affect on the timing of a summer flood and has no influence on the extent or duration of the flooding.

As a further theoretical exercise, we have provided a tentative indication of the impact of drawing down Lough Ree further than ESB Guidelines currently allow, prior to the flood events of 2008 and 2009. This analysis indicates that the potential additional benefit in terms of reduced impact on flooding for the particular conditions experienced in 2008 and 2009 would be relatively small, delaying flooding by no more than a further day in 2008 and possibly 3 days in the atypical summer flood event of 2009. With these modes of operation, drawdown is required over an extended period of a month or more. Therefore, unless a reliable long term weather forecast was to become available, there would be an increased risk of low water levels towards the end of a dry summer.

Recommendations

The recommendations from our assessment of the operating regulations and procedures of the control structures affecting flood water levels to the callows area, can be summarised as follows:

1. Immediate or Short Term Actions

- In the short term, operation of the Athlone Sluices should continue to follow ESB Guideline 2.7.3.2. ESB Guideline 2.7.3.2 is intended to “*optimise storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years*”.

2. Issues identified that should be considered by the wider CFRAM Study

- Development of the hydrological and hydraulic modelling of the River Shannon which could be used to assess:
 - The extent to which realistic improvements in channel capacity through and downstream from the callows might reduce flood risk.
 - Whether the attenuation of flows from the Suck or Brosna could reduce flood risk through the callows.
- Once new topographic survey is available through the CFRAM process, compare river cross sections at critical locations along the Shannon with available historic cross sections to determine whether siltation has resulted in a reduction in the channel conveyance.

1

Defining Scope of Report

1.1 Initial Brief

The initial brief for the River Shannon Level Operation Review was included in Stage II Specific Brief: 2.7 Section 1.3.2 Project Programme as follows:

“The Consultant shall review the operating regulations and procedures of the control structures and dams on the main body of the river Shannon between Lough Allen and Limerick City (as operated by ESB and Waterways Ireland), and identify potential, acceptable improvements to the operation of the structures with respect to flood risk management within six (6) months of Commencement, and shall provide a report on the findings of this analysis as an accompaniment to the Inception Report.”

1.2 Scope of the Report

This report on the Technical Assessment: River Shannon Level Operation Review is delivered as part of the wider Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study. It is identified in the Project Brief as an early project deliverable.

This in-depth, desk-based, report has been developed as an analytical assessment of the available levels, flows and sluice control operations at key locations along the River Shannon. This was done in advance of undertaking any topographic survey, detailed catchment wide hydraulic review or hydraulic modelling. As such, no new or bespoke data has been collated for this study.

The intention of this report is to determine lessons learnt and identify any potential measures that could be taken to reduce flood risk and / or flood extents attributed to the control operations on the River Shannon. The reason for the timeframe for this deliverable was to facilitate OPW in converting these potential measures into any ‘early wins’ which might be implemented before the Shannon CFRAM Study is completed.

It should be noted that the findings and recommendations of this report have been reached without the benefit of the detailed hydrological analysis and hydraulic modelling which is being carried out between 2012 and 2014, as part of the Shannon CFRAM Study. These findings and recommendations are therefore interim and may be subject to refinement once the more detailed technical analysis has been undertaken.

1.3 Intended Audience and Assumed Knowledge

This report on the Technical Assessment: River Shannon Level Operation Review is one of many deliverables required as part of the Shannon CFRAM Study. As specified, it is an accompaniment to the project Inception Report for Unit of Management (UoM) 25 and 26 and does not duplicate any of the project background or catchment descriptions provided within the Inception Report.

This Technical Assessment is not intended to be read in isolation without the supplementary information provided in the Inception Report.

It is assumed that the audience for this report has an informed background knowledge of the general catchment description, flow characteristics, various conflicts of interest, key locations and major tributaries along the fluvial Shannon.

The document contains a complex, analytical review of various data sources and attempts to draw conclusions through an educated discussion. It is very much a 'Technical Assessment' and should be considered accordingly.

1.4 Brief Details of the Shannon Catchment

Figure 1.1 shows a map of the whole Shannon catchment down to Limerick City, with an indication of the location of the existing water level control structures. Figure 1.2 shows a longitudinal section of the 223 km length of the Shannon from Lough Allen to Parteen Weir near Limerick. Figure 1.2 shows that the river falls only some 15m over this length with an average gradient of about 1 in 15,000.

Table 1.1 Key Shannon Catchment Characteristics

Location	Approx Catchment Area (km ²)	Lake Area (km ²)	Average Discharge (m ³ /s) 1932-1991
Lough Allen	425	35	14.4
Lough Ree		106	
Shannon at Athlone Weir	4,580		98
River Suck	1,600		
River Brosna	1,370		
Shannon at Banagher	7,980		
Lough Derg		120	
Parteen Weir / Ardnacrusha	10,410		176

1.5 Ordnance Datum

All levels referred to in this report are quoted to "Ordnance Datum Poolbeg". This relates to the low water mark of the spring tide on the 8 April 1837 at Poolbeg Lighthouse, Dublin. Initially fixed for County Dublin, it was adopted as the national datum approximately five years later. Heights above this datum were originally given in (Imperial) feet. The principal Shannon Navigation structures constructed in the 1840s and subsequent works undertaken in the 1920s and 1930s for the Shannon Hydro-electric Scheme were all based on this datum.

More recently, Malin Head Vertical Datum was fixed as Mean Sea Level of the tide gauge at Malin Head, County Donegal. It was adopted as the national datum in 1970 from readings taken between January 1960 and December 1969. All heights on National Grid mapping since then are in International metres above this datum.

Malin Head datum is approximately 2.7 m above the Poolbeg Lighthouse datum, although this can vary with location by up to +/- 0.24m depending on the accuracy of the original local primary benchmark established in the nineteenth century. At Athlone the difference is quoted by Ordnance Survey Ireland (OSI) as 2.766m and at Limerick as 2.663m.

Both Waterways Ireland (WI) and the Electricity Supply Board (ESB) maintain their records of water levels as metres above the original Poolbeg datum. The published operating procedures for the water level control structures also use the Poolbeg datum. For consistency with previous work, this report therefore quotes all levels to Poolbeg datum.

1.6 Outline of the Report

This report is structured into the following Sections:

Section 2 constitutes a brief literature review of the most pertinent reports and other documents relating to water level control on the River Shannon.

To help understand how the current operating regime on the River Shannon has developed over more than two centuries, **Section 3** provides an overall historical perspective concentrating on changes to the water level control structures and their mode of operation.

Current stakeholder responsibilities are summarised in **Section 4** and details of initial consultation with three of the principal stakeholders are provided in **Section 5**.

Section 6 summarises the hydrometric data which was available for this study.

The current operating procedures for each of the water level control structures on the River Shannon are explained in **Section 7**.

Section 8 provides a summary of summer water level variations in the callows area based on the 80 year record of daily water levels maintained by ESB.

A review of water levels, flows and weir operations over recent summers is presented in **Section 9**.

Section 10 examines the extent to which potential changes to the Athlone Weir operating procedures during the summer floods of 2008 and 2009 might have reduced the risk of flooding in the callows area.

Section 11 presents conclusions and recommendations.

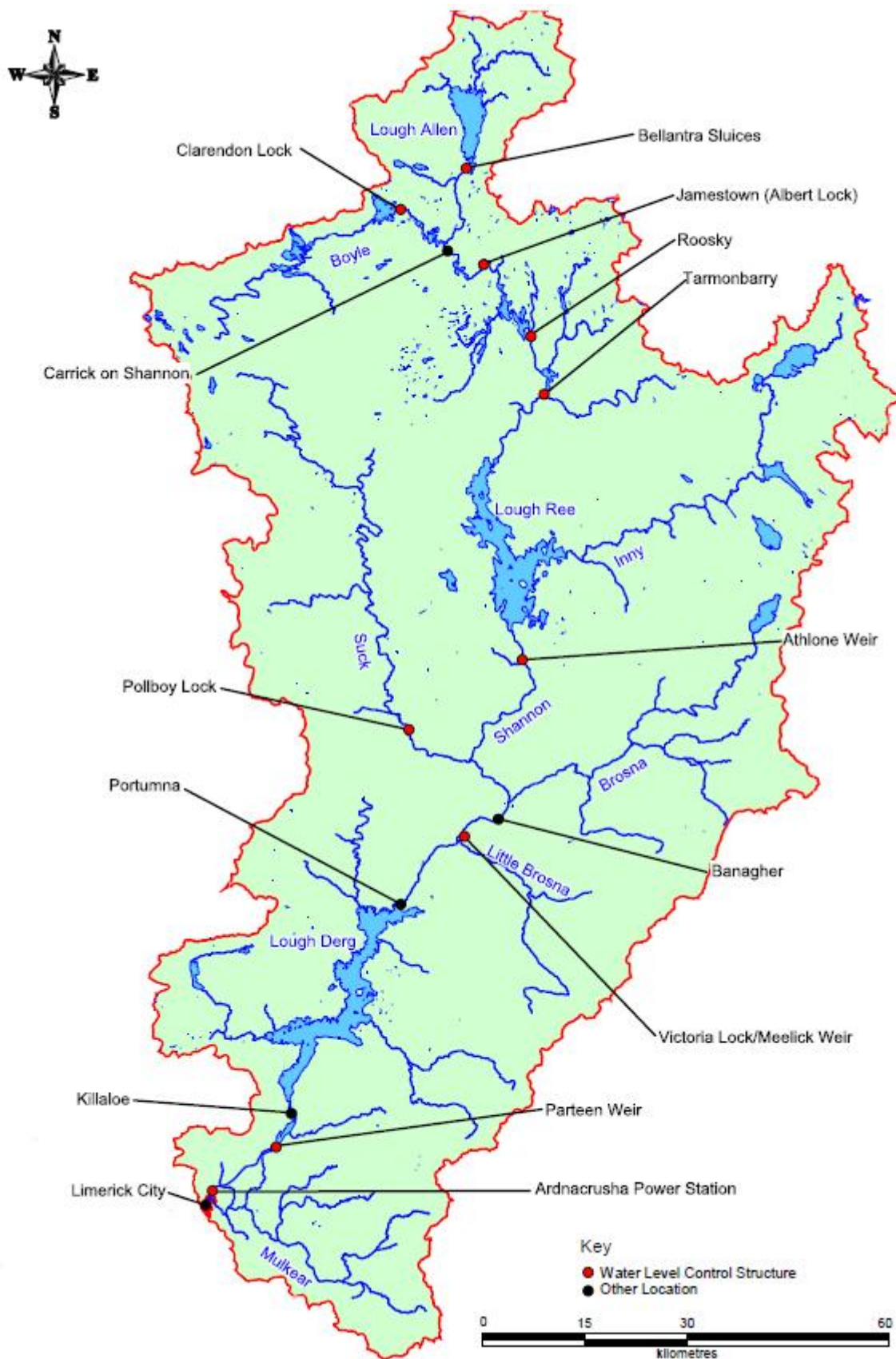


Figure 1.1 Map of the Shannon Catchment

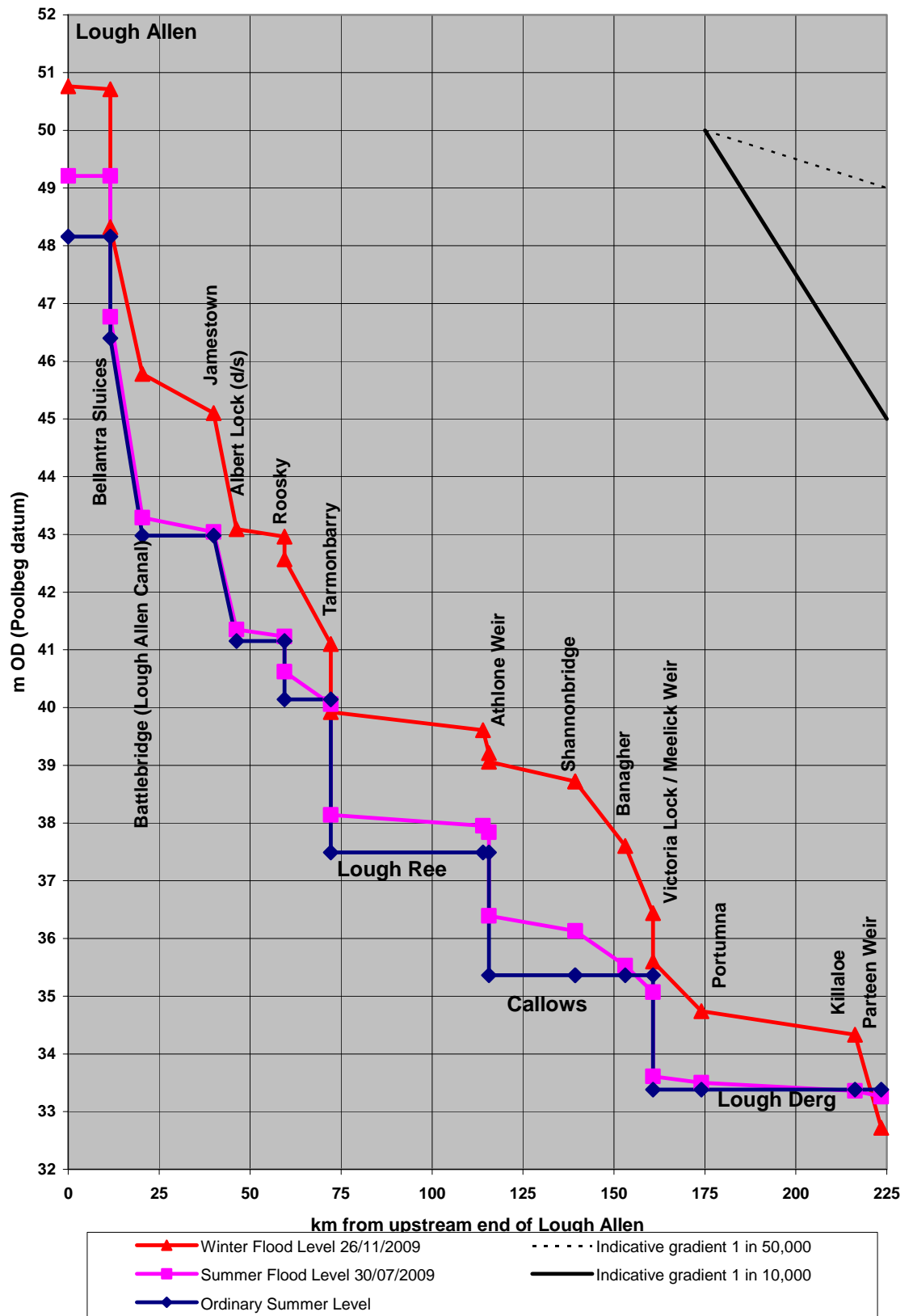


Figure 1.2 Longitudinal Section of the River Shannon

2

Literature Review

2.1 Flood Risk Management Concerns and Opportunities

Over the last two centuries numerous reports have addressed concerns and possible solutions to the issues of flood risk management on the River Shannon. Details of the most relevant of these reports are presented below in reverse chronological order, with a summary of the conclusions from the more recent reports.

2.1.1 2010 Houses of Oireachtas Report

Fourth Report of the Joint Committee on the Environment, Heritage and Local Government; The Management of Severe Weather Events in Ireland & Related Matters; July 2010; A10/1019

The Joint Committee began considering the flooding events in December 2009, but as their magnitude and severity increased, and then a period of severe cold began, it widened its deliberations to consider the severe cold weather, and later agreed to prepare a report on the management of severe weather events more generally, based on the experiences between November 2009 and January 2010.

To discuss the management of the Shannon, the Joint Committee invited representatives of a range of agencies with interests or responsibilities concerning the river to come before it. In addition to OPW, these included the National Parks and Wildlife Service, the ESB, the Central Fisheries Board, the Irish Farmers Association, Waterways Ireland, Bord na Móna and the Heritage Council.

Recommendations of the Joint Committee's report specific to the Shannon are relatively limited and include:

- *“The OPW’s funding for flood risk management should be substantially and strategically increased to reflect levels of flood risk now known to exist in several major river catchments. The OPW should commence and if possible accelerate the implementation of the Lee CFRAMS, commence the Shannon CFRAMS and those of other major river systems;*
- *The Government should consider and assess the effectiveness with which rivers and inland waterways are managed, controlled and regulated, and consider the options for enhancing the co-ordination of responsibilities currently carried out by a multitude of agencies, including but not limited to the option of appointing a single rivers agency or a single agency for the River Shannon.”*

2.1.2 2004 OPW Report

Flood Risk Management Opportunities, Pre-Feasibility Study, Final Report (Design Section, Engineering Services, OPW, September 2004 ref 1484/RP/001/C).

The objectives and focus of this study was set out (Section 1.4) as follows:

“The objectives of this River Shannon Flood Risk Management Pre-Feasibility Study were to:

- Review at pre-feasibility level previously identified flood relief options for the River Shannon,*
- Investigate other options at pre-feasibility level that are developed as part of the study, and*
- Identify potentially viable options that may warrant feasibility stage investigation.*

A further more-general objective was that at the end of the study, there would be a critical mass of institutional knowledge available that could be applied where appropriate to a number of future needs. This knowledge is of long-term value, and may influence a variety of other ongoing or future studies or functions; for example, the current Shannon River Basin Management Project (conducted under EU Water Framework Directive, 2000/60/EC), or the development plans of the local authorities. Equally, the policies that are developed by other projects may well influence or enhance the viability of a number of the options considered in this pre-feasibility study, e.g. the water body classifications, developed under the Shannon River Basin Management Plan.

From the outset of the study it was considered essential that key affected or interested parties be consulted and involved, to ensure that their issues and interests were considered as options were developed. There was also a requirement to include the ‘non-structural options’ into the mix, because they are a fundamental component of any contemporary flood relief strategy.”

In response to some of the key issues raised by interested parties, the following was concluded (Executive Summary):

- “The ESB Regulations for managing Loughs Derg, Ree and Allen provide, on balance, optimum management of floods within existing storage and land control capabilities.*
- The effects of high Lough Derg levels do not extend upstream above Meelick Weir.*
- Recent reports confirm that both the ESB and Waterways Ireland manage water levels in compliance with their respective Regulations and Rules.*
- It is evident that peat silt has entered the River Shannon system and tributaries in large quantities. However, the river resurvey indicates that while there are areas of the river with significant deposits of peat silt, there are long reaches (the majority, based on the current river resurvey) that are unaffected.*
- Bord na Mona now has in place responsible strategies for minimising discharges of peat silt.*

- Analysis of river records at Banagher for the last 60 years indicate that the decade from 1993 to 2002 had the highest number of flood events; conversely the same decade had the lowest number of 'seasonal' (between spring and autumn) floods.
- The extent of aquatic and riverside vegetation has increased over the last 50 years, and at constricted locations such growth will have some effect on flood levels.
- The River Shannon and its callows are, over much of their length, considered to have environmental significance on an international scale.
- The River Shannon, like many other large accessible rivers, has many conflicting and strongly competing interests for its management regime and resources.
- This study indicates that there are potential benefits in terms of transparency and accountability, if one organisation is responsible for overseeing all flood management operations, prior to, during and after floods within the context of a catchment based Flood Risk Management Planning framework."

The conclusions relating to operation of the existing water level control structures were (Section 6.1) as follows:

"Loughs Derg, Ree and Allen Water Level Management

The investigations conclude that there are no major flood relief benefits available by managing the Lough Derg storage in a different way, and that there are no impacts on flood levels above Meelick Weir from the operations in Lough Derg.

As part of the Shannon power scheme developments the weir at Killaloe was removed, and there were several stages of channel improvements. These works improved discharge capacity from Lough Derg, allowing it to run at lower levels for equivalent flows. Further improvements in this reach of channel are not warranted, as lake levels have no effect above Meelick Weir.

With the existing outlet control arrangements at Lough Ree there is little, if anything, that can be done to provide better flood relief by changing the ESB operating Regulations.

There are reasonable grounds for the minimum Lough Ree navigation levels contained in the ESB Regulations, but the benefits to navigation are at the expense of landowners at the perimeter of Lough Ree and on the callows downstream. Based on historic records these benefits may occur approximately once every four or five years. If improvements were made to the control of the Lough Ree storage, then for a five to ten year seasonal flood, the farmers could benefit from a less extreme flood and possibly two to three days less flooding. The reduced duration of flooding in summer is unlikely to be significant because most of the damage is done by the initial inundation.

The current rules for managing floods at Lough Allen achieve, on balance, reasonable outcomes.

Navigation Structures

Reports by Kirk McClure Morton (2001) and the Shannon River Basin Management Project (2003) confirm that, for the floods considered, both the ESB and Waterways Ireland have managed water levels in accordance with the regulations established by both organisations.

The structures that were built in the Meelick area (the weir with associated boards and sluices, the walkway, and the raised ground at the gun battery) do adversely affect upstream flood levels”.¹ “This appears to have been recognised shortly after their construction and would appear to have been the impetus for the excavation of the New Cut and sluice barrage. The benefit of the New Cut may not fully compensate the adverse effects. To assess the specific effects of the Meelick Weir board operations, and whether there is an impact on farming operations, requires more sophisticated modelling tools and information than were available for this study.”

With regard to **Coordinated Flood Management** the report (Section 6.1) concluded:

“Notwithstanding compliance by the ESB and WI with their respective operational regulations and rules, there is a case for one organisation being responsible for overseeing all flood management operations on the River Shannon prior to, during and after a flood event.

It is appropriate that one organisation should be responsible for overseeing the various flood management operations; this independent overview would provide a necessary element of transparency. The operational roles of the ESB and WI, as they stand, would still continue. If a decision were taken to provide a flood warning service then the overseeing role could sit well with flood warning responsibilities. As part of the flood warning procedures there should be a detailed review of the thresholds and mechanisms for operating the navigational sluices and controls.”

2.1.3 2003 Shannon River Basin Management Project

Current Management of Water Levels, River Shannon, August 2003 (Ref. 5321.00/AGB/RW08)

The objective of this report was to undertake an independent review of the management regimes currently operated on the River Shannon by ESB Power Generation and Waterways Ireland in order to facilitate the decision making process in delineating Artificial and Heavily Modified Water Bodies, in connection with the Water Framework Directive.

Much of the work presented in the report was taken from a previous study undertaken by Kirk McClure Morton entitled ‘Study of the Current Management of the Water Levels of the River Shannon, April 2001’ which was funded by ESB and Waterways Ireland.

Having considered a number of major winter floods the report concludes:

“The assessment of a range of alternative management options indicated that there is no significant impact due to any of the controls operated by ESB or Waterways Ireland on the system. These findings concur with historical investigations which identified that there was no simple single solution to the River Shannon flooding problem.”

¹ It should be noted that the out-of-bank civil works in the broader Meelick area that formed part of the Navigation Scheme such as the embankments along the approach canal to Victoria Lock and the emplacement for the gun batteries very effectively cut out all overland flow.

2.1.4 2003 OPW Report

Preliminary Assessment of the Shannon Flood Problem, Final Report (Design Section, Engineering Services, OPW, February 2003).

This report summarised the findings of earlier reports from as far back as 1863 as follows:

- *“There is no single, simple solution to prevent flooding along the River Shannon, and a combination of works would be required to reduce flood levels by a significant degree.*
- *The principal cause of flooding between Meelick and Athlone is the shallow gradient of the river and the limited channel capacity along this reach. Channel works along this reach would be critical to the success of any general scheme.*
- *The artificial control structures constructed for the purposes of navigation and power supply, including Meelick Weir, do not have a significant effect on flood levels.*
- *The removal of Parteen Weir and Ardnacrusha power station would not increase the discharge capacity from Lough Derg under existing conditions due to constrictions and limited channel capacity at Killaloe and downstream.*
- *Localised dredging upstream of Meelick Weir was not found to have a significant impact on flood levels.*
- *The issue of siltation has repeatedly been identified as a potential problem, but has never been quantified or proven as a problem.*
- *Enhanced management of storage in Loughs Derg and Ree (and possibly Lough Allen) could form part of a scheme for relieving flooding from short-duration floods, but would not eliminate major winter flooding as a stand-alone option. However, raising or lowering maximum and minimum lake levels respectively could have serious implications for riparian properties and river system activities.*
- *The use of embankments as a general flood relief option is not likely to be viable due to local soil types, but may have localised applications.*
- *The use of river diversions for flood relief would either be entirely uneconomical or offer no significant benefit.*
- *The development of an effective storage area above Roosky Weir would be uneconomical due to significant inundation of infrastructure, properties, etc.*
- *The impacts of any scheme would need to be assessed in relation to the economic benefit, environment, navigation, fisheries, tourism, etc.*
- *A cross-body Shannon Agency or Authority should be established to discuss and coordinate activities on the river and within the catchment.*

It must be emphasised again that many of these conclusions, especially those reached in the earlier reports need to be reviewed in the light of changed circumstances in the interim. In some cases these changes will impact negatively on the possibility of relief works, e.g. increased awareness of the importance of environmental considerations will make most proposed works more difficult and costly. In other cases improvements in construction techniques may mean solutions previously considered not to be feasible can be looked at again.”

The outcome from this preliminary assessment was the Pre-Feasibility Study described in Section 2.1.2.

2.1.5 2001 Kirk McClure Morton Report

Study of the Current Management of the Water Levels of the River Shannon, April 2001, Kirk McClure Morton (funded by ESB and Waterways Ireland).

As reported in the Shannon River Basin Management Project report (see Section 2.1.3), Kirk McClure Morton carried out an independent review of management regimes on the Shannon and concluded:

1. *"The Shannon system has experienced a history of severe flooding incidents over the past 200 years. This is due to natural characteristics of the system especially the low gradients from downstream of Lough Allen to Parteen Weir.*
2. *Reports on previous flood events and proposed relief schemes were reviewed. The winter 1994/95 and 1999/00 events were some of the most severe experienced on the Shannon.*
3. *In 1956 the Rydell report concluded that there was no simple or obvious solution to flooding and put forward a series of measures for further consideration.*
4. *A review of flooding by a sub-committee of the Joint Committee on Public Enterprise and Transport recommended immediate action to raise flooded roads and undertake studies to identify the extent of flooding in order to instigate a once-off compensation for affected persons.*
5. *Water level is controlled at a number of sites on the Shannon for navigation and hydro-electric power generation by Waterways Ireland and ESB. The operation of these controls is in accordance with Regulations established by both organisations. Review of actions during recent events has confirmed that ESB and Waterways Ireland are satisfactorily co-ordinating their activities in accordance with operational requirements and that these controls were not seen as contributing to flooding problems.*
6. *ESB International's verified model of the Shannon and previous modelling studies by OPW have been able to predict water levels along the main Shannon River channel.*
7. *Simulations indicate that alterations to Meelick Weir would have no impact on water levels in the worst hit flooded areas. These results confirm that the restricted channel capacity between Athlone and Meelick combined with the influence of significant inflows from the Rivers Suck and Brosna are the main contributory factors in flooding in this worst affected portion of the Shannon.*
8. *Simulations indicate that even if Ardnacrusha Power Station was not in operation during the most recent flood event this would have had no impact on water levels in the worst hit flooded areas. However, such a scenario would most likely result in severe flooding downstream of Parteen Weir to Limerick.*
9. *The management of storage at Lough Allen and Lough Ree would provide no significant impact on flooding in the Shannon.*
10. *The assessment of a range of alternative management options indicated that there is no significant impact due to any of the controls operated by ESB or Waterways Ireland on the system".*

2.1.6 2000 and 2002 House of Oireachtas Reports

As reported in the Preliminary Assessment of the Shannon Flood Problem (see Section 2.1.4), an Interim Report on Flooding on the River Shannon “was prepared by a sub-committee of the Joint Committee on Public Enterprise and Transport who were requested by the Houses of the Oireachtas to review issues relating to management of the Shannon following flooding over the Christmas and New Year period 1999-2000. The principal conclusions of the report were:

- *The flood problem on the Shannon was mainly due to natural causes but appears to be worsening.*
- *The Summer Scheme, while likely to be extremely costly, appeared to be the most economically viable, although the cost-benefit and impacts on the environment, navigation, tourism, etc., would need to be reassessed.*
- *Some elements of the Scheme should be prioritised, e.g. raising local infrastructure (mainly roads) and a once-off compensation scheme.*
- *An agency, with maintenance funding, should be established to address issues such as siltation and hydraulic controls.*
- *Bord na Mona should contribute to dredging costs and the EPA should require more regular and stringent monitoring of IPC licensed sedimentation ponds.*
- *The use of Lough Allen and Lough Ree for flood storage and attenuation should be discussed with ESB.*
- *Further investigation should be undertaken to assess the extent of flooding and constraints on the possibility of increased storage in Lough Ree.*

The Joint Committee issued a final report in March 2002. The Sub-Committee concluded that the management of the Shannon Catchment could not be expected to improve as long as the present organisations continued to operate without a co-ordinating framework. The Joint Committee recommended that, that co-ordinating role be assigned to the Western Development Commission. The Joint-Committee emphasised that it did not consider that, in the time and within the resources available, it could hope to have produced a definitive blueprint for the effective management of the Shannon catchment.”

2.1.7 1988 Delap and Waller Report

As reported in the Preliminary Assessment of the Shannon Flood Problem (see Section 2.1.4), “consultants Delap and Waller were appointed by the IFA to make a technical assessment of the Shannon flood problems. The report’s principal conclusions were:

- *There is no single, simple solution to the overall problem.*
- *Localised flood relief may be achieved through embankment and / or drainage works.*
- *Lowering the minimum water level for navigation by 150mm between Athlone and Meelick would have no significant impact in terms of flood relief, but would improve the drainage of the callows.*

- *The following proposals were found to be ineffectual or unjustifiable for flood relief:*
 - *the removal of Meelick Weir,*
 - *the reopening of the Cloonaheenoge Canal,*
 - *the removal of islands in the main channel,*
 - *the removal of silt in the New Cut,*
 - *prompter operation of sluices.*
- *Co-operation between OPW and ESB in relation to operation of controls is effective, but work should continue to examine possibilities for reducing summer flood levels through the management of levels in Loughs Allen and Ree.*
- *Proper maintenance of Bord na Mona's siltation ponds is essential to minimise the discharge of silt into the river.*
- *The Summer Relief Scheme (1956, 1961) should be further investigated, but would require an Environmental Impact Assessment.*
- *A forum or agency should be created to co-ordinate activities and management of the Shannon."*

2.1.8 1988 OPW Analysis of Meelick Weir

As reported in the Preliminary Assessment of the Shannon Flood Problem (see Section 2.1.4), *"concurrently with the Delap and Waller Report the OPW undertook an investigation of the impact of Meelick Weir and channel restrictions on flood levels between Meelick and Banagher using a computer model. The report examines the existing situation and the effects on water levels upstream to Banagher of removing the weir, and of removing the weir and widening and deepening the channel at the weir and for a short distance downstream. The report concludes that water levels for medium, or 'wet summer', flows could be lowered upstream by up to 300mm, but as these flows are in-bank, no benefit would result in terms of flood relief. The works would however have a negligible impact on levels even a short distance upstream during flood conditions. These conclusions concur with those of earlier reports."*

2.1.9 Earlier Reports

The Preliminary Assessment of the Shannon Flood Problem (see Section 2.1.4) referred to the following reports prepared since 1863. Copies of the two reports marked with an asterisk have been made available for this study:

1978 OPW Assistant Chief Engineer: reviewed the Rydell and 1961 reports and subsequent progress.

***1961 OPW/ESB** Report which presented preliminary investigations of a number of the more favourable elements proposed in the Rydell Report and recommended, *inter alia*, further analysis of a "Summer Relief Scheme" and the establishment of a Shannon Basin Interagency Committee.

***1956 Rydell Report:** The Rydell Report was commissioned following flooding in 1954. Rydell was assigned to the OPW from the U.S. Army Corps of Engineers at the request of the Irish Government to make a preliminary assessment of the flooding problems of the Shannon.

1955 OPW: A general review of the Shannon flood problem was commissioned following the flood of 1954.

1951-1955 ESB: Various reports were undertaken by the ESB during this period, principally relating to the use of water and potential for hydro-power on the Shannon and its tributaries.

1940 Drainage Commission: This comprehensive report was commissioned to assess arterial drainage throughout Ireland and included the Shannon. The report reviews the general flood problems of the basin and the history of flood control measures implemented. It discussed a number of potential solutions including channel improvements and the use of embankments with pumping facilities, but found both of these options to be economically unfeasible. The report recommended some minor works of which little was subsequently carried out.

1938 Board of Public Works: This study was primarily commissioned to evaluate Shannon navigation, but the scope also discussed flood problems. The report is potentially a good source of historic information on flooding in the Shannon Basin.

1887 Allport Commission²: A report from a Royal Commission covering proposed arterial drainage schemes as well as the Shannon Navigation. It recommended excavation to lower the navigation level between Killaloe and Athlone and putting in sluices to control Lough Allen.

1863 John F. Bateman: This report was commissioned in response to a major flood in 1860/61 to examine the impact of navigation works around Victoria Lock and Meelick Weir and potential flood relief measures. The recommendations included:

- Use of Lough Allen for flood storage
- Channel improvements (a new channel downstream of Meelick, the 'New Cut', which was subsequently completed in the 1880s)
- Provision of sluices in fixed weirs (this work was also undertaken in 1880s)

This list of earlier reports may not be comprehensive. In particular, no reports are listed which refer to the changes introduced in the 1920s with the construction of the Shannon Hydro-electric Scheme, nor with the subsequent installation of the current Bellantra Sluices outlet control for Lough Allen in the 1930s.

2.2 Water Level Operations

In addition to references in the reports on wider flooding issues referred to in the reports listed above, a number of reports and other documents are available relating specifically to water level operations at the various control structures.

2.2.1 Regulations and Guidelines for the Control of the River Shannon (ESB)

The current operating procedures for the principal control works on the Shannon remain essentially as defined in the Electricity (Supply) Act, 1927 and subsequent amendments. Responsibility for determining the operation of the structures which control the three major lakes (Loughs Allen, Ree and Derg) lies with ESB, in accordance with the current version of the document *Regulations and Guidelines for the Control of the River Shannon* (ESB November 2003, with minor revisions in 2008).

Relevant extracts from this document for the various control structures are quoted in Section 7.

² Details from "The Shannon Navigation", Ruth Delany, The Lilliput Press in association with Waterways Ireland, 2008 (page 153)

2.2.2 Water Level Control on River Shannon between Athlone and Meelick (WI)

This is an internal report by Waterways Ireland dated March 2011 and presents detailed records of water levels and sluice operations for the periods leading up to flood events in November 2009, March 2010, September 2010 and December 2010.

The overall picture presented is that during these periods and in accordance with their operating procedures, Waterways Ireland progressively opened all the sluices at Meelick Weir and at Marlborough in the New Cut as upstream water levels started to rise.

The report concludes that the main cause of the initial flooding of the callows between Athlone Weir and Meelick is the inflows from the River Suck combined with the flat gradient and restricted channel capacity between Athlone and Meelick.

2.2.3 Shannon Navigation – Water Levels and Sluice Openings (WI)

The Pre-Feasibility Study (OPW, September 2004) refers to a WI document ‘Shannon Navigation – Water Levels and Sluice Openings’. WI have confirmed that the current operating procedures stated in the March 2011 document referred to above are the same as those in the WI document referred to in the OPW 2004 report.

3 Overall Historical Perspective

3.1 Overview

The literature review in Section 2 confirms that concerns relating to water levels on the Shannon from the perspective of different interest groups have continued over an extended period.

A recent book published in association Waterways Ireland (“The Shannon Navigation”, Ruth Delany, The Lilliput Press in association with Waterways Ireland, 2008) provides a comprehensive history of the development of the river, initially as an improved transport artery with proposals for navigation works being put forward from the end of the 17th Century.

The current major works on the river date from three main periods and with three different primary objectives:

- **1840s Navigation** : construction of the principal navigation locks and associated fixed weirs, including Athlone and Meelick, enlargement of restricted channel sections and construction of new bridges.
- **1880s - 1890s Mitigation for Flood Relief**: construction of the New Cut at Meelick together with the introduction of sluices in the original fixed weirs and control works at Bellantra, the outlet of Lough Allen. The installation of the sluices at Athlone Weir date from this period and provide the facility for drawing down the level of Lough Ree below the fixed weir crest, potentially providing some flood storage in addition to enhancing low summer flows in the reach downstream.
- **1920s-1930s Hydro-electric Generation**: construction of the Shannon Hydro-electric Scheme with major works at Parteen Weir and Ardnacrusha Power Station commissioned in 1929, followed by the current Bellantra Sluices in 1938.

3.2 Historical Timeline

Table 3.1 presents an historical timeline in a summary matrix form, showing the varying impact and influence of the key stakeholders over the best part of three centuries. We have attempted to include the most significant features relating to the current water level management regime. Inevitably in such a simplified summary other features of historical interest have had to be omitted.

This overall historical perspective is of fundamental importance in understanding how and why the current operating regime on the Shannon has developed.

Table 3.1 Overall Historical Perspective of the Development of the Shannon and Varying Impact on Key Stakeholders

Period	Navigation	Hydropower	Farming and Flood Risk	Environment
18th Century	Initial improvements with short canalised sections bypassing restricted channel sections.			
1840s	Major construction of weirs and locks. Athlone Weir constructed to provide ordinary summer level in Lough Ree of 123 ftOD (37.49 mOD).			Fishpass incorporated on original fixed weirs (eg at Athlone).
1850s - 1890s	Commercial traffic growth limited, particularly at Athlone and upstream. Allport Commission established in 1886 recommended abandonment of navigation above Athlone.		Increased flooding experienced. Sluices installed in fixed weirs in 1880s. Parallel New Cut constructed with sluices to provide additional discharge capacity at Meelick. Bellantra Sluice to control Lough Allen.	
1920s – 1930s	Decline in commercial traffic. Statutory Minimum Navigation Level in Lough Ree set at 121 ftOD (36.88 mOD). Canal to Lough Allen abandoned.	Ardnacrusa Power Station commissioned. Level control of Loughs Ree and Derg exercised to ensure adequate flow to sustain energy output in dry summers. New Bellantra Sluices provided additional regulation in Lough Allen from 1938.	Crest of Meelick Weir lowered and weir boards installed to increase discharge capacity. Embankments and pumps installed on west bank between Meelick and Portumna (ref Delany, 2008, p219).	
1950s – 1960s	Negligible commercial traffic. Abandonment of navigation considered but potential of recreational usage recognised.	Storage still utilised for power generation but of lesser importance as ESB system expands.	Major winter flood event in 1954 highlighted concerns expressed in earlier years.	New salmon lift at Ardnacrusa and fish hatchery at Parteen (ref Delany, 2008, p220).
1970s	Substantial increase in recreational usage. Reliable safe summer access desired to a greater proportion of the area of Lough Ree	Storage in Loughs Allen and Ree becomes of lesser importance to ESB. Agreement to restrict summer drawdown in Lough Ree to 123 ft OD (37.49 mOD) until mid August and to 122 ftOD (37.19 mOD) until 1 October.		Wildlife Act 1976 introduced to protect wildlife, habitats, natural heritage etc.
1980s - 1990s	Waterways Ireland established 1999. Navigation to Lough Allen re-opened. New navigation on River Suck to Ballinasloe via Pollboy Lock			Increasing recognition of environmental concerns and the value of the callows as a habitat of European significance.
2000s	Extensive recreational usage with summer season extended.	ESB does not store water in Loughs Allen and Ree for power generation purposes.	Significant summer floods as well as highest recorded winter flood in November 2009.	

With respect to the works undertaken in the 1880s and 1890s, an article in the Journal of the Irish Society for Archives, Autumn 1994 (“The archives of the Office of Public Works and their value for local history”, Rena Lohan, Archivist, National Archives) provides some additional background:

“A major impetus was given to the various [drainage] schemes on the Shannon by the very severe flooding in 1861 of the lands bordering the river. In an effort to relieve the threat of further severe flooding the Shannon Act, 1874 (37 & 38 Vict. c.60) was passed. This provided for a survey and valuation of the lands by the Board. It proved impossible to get the required number of assents from landowners and a reduced scheme was carried out at public expense during 1880–1884. The other major drainage project carried out in this period was that of the Suck Drainage District, which was certified as complete in 1895.”

4

Summary of Stakeholder Responsibilities

4.1 Introduction

This section aims to outline the responsibilities of the following Stakeholders with an interest in the operation of the water levels along the fluvial River Shannon:

- Electricity Supply Board
- Waterways Ireland
- National Parks and Wildlife Services
- The Office of Public Works
- Irish Farmers Association (landowners)

Much of the information provided in this section has been extracted largely verbatim from the Pre-Feasibility Study Final Report (OPW, September 2004).

4.2 Electricity Supply Board (ESB)

4.2.1 Mandate

The ESB has a mandate to generate electricity, and its responsibilities on the River Shannon relate to the hydro-electric scheme. The Shannon Scheme created an essential framework and platform for the social, economic and industrial development of Ireland. Ardnacrusha, the focal point of the scheme, was the first major hydro-electric generating station constructed in Ireland and was commissioned in 1929.

4.2.2 Legislation

Legislation regulating the ESB's operations on the Shannon is contained in the Electricity (Supply) Acts 1927 to 1988. The Electricity Supply Amendment Act (No. 2) 1934 deals specifically with lake levels.

4.2.3 Water Management

ESB manages the three lakes on the Shannon in accordance with the Regulations and Guidelines for the Control of the River Shannon (Water Management Document). These Regulations and Guidelines do not have any statutory basis but take account of dam safety and reflect the outcomes of longstanding consultation with key affected parties. The Water Management Document contains ESB's day to day operational Guidelines in Part 2, which is more discretionary in application than the Regulations in Part 1. Specifically the Regulations and Guidelines together have three main objectives:

- To ensure dam safety at both Lough Allen and at the Lower Shannon Dams (i.e. the embankments plus Parteen Weir and Ardnacrusha Dam). In this regard the Lower Shannon Dams are required to pass a flood event with an Annual Exceedance Probability (AEP) of 0.01% (1 in 10,000) while Bellantra Sluice structure and associated embankment dam at the outlet of Lough Allen is required to pass a 0.1% (1 in 1,000) AEP flood event.
- To maintain, as far as possible, minimum and seasonal navigation levels in the main lakes. Maintaining these minimum and seasonal levels assures

adequate water supply and quality for Local Authorities and Inland Fisheries Ireland.

- To minimise flooding as far as possible for the agricultural sector and the general public.

ESB collects and maintains records of rainfall, river and lake levels and flow data. Even though ESB has no responsibility to supply flood warnings under their regulations, it issues twice weekly lake level forecasts to all the relevant stakeholders since 2010.

4.2.4 Operation

Ardnacrusha initially met all of Ireland's power demands; it now supplies half of the two to four percent hydropower contribution to national demand. It is an important source of clean renewable energy. The operation of Ardnacrusha varies throughout the year depending on inflows to Lough Derg. During flood periods Ardnacrusha Station operates on full load around the clock.

Initially, power generation at Ardnacrusha utilised the storage available in Lough Derg only. Work was subsequently commissioned on Lough Allen outlet and the 1934 Electricity (Supply) Act 1934 facilitated more effective use of the water stored in Lough Ree and Lough Allen.

Early operation of the station relied on careful management of water storage in Loughs Derg, Ree and Allen to optimise storage for power generation. Now with diversification of supply, power generation at Ardnacrusha again utilises the storage available in Lough Derg only. ESB no longer has any strategic interest in Lough Allen and Lough Ree from the point of view of power generation. However, as noted above these lakes are managed by ESB to take account of dam safety (in the case of Lough Allen), farming, leisure and environmental interests.

4.3 Waterways Ireland (WI)

4.3.1 Mandate and Legislation

Waterways Ireland (WI), the North/South Implementation Body for the inland navigable waterways system, was established in 1999 as provided for in the British - Irish Agreement Act 1999, (formalising the Belfast/Good Friday Agreement). WI operates under the policy direction of the North/South Ministerial Council and the British and Irish Governments, and is accountable to the Northern Ireland Assembly, the UK Parliament and the Houses of the Oireachtas.

WI took over the inland navigation role previously managed by Dúchas Waterways and prior to that the OPW. WI is therefore the Body responsible for the management, maintenance, development and restoration of the Shannon Navigation principally for recreational purposes.

Waterways Ireland inherited the powers and functions from the Commissioners of Public Works. These powers and functions arose mainly from the acts that set up the Shannon Commissioners, later the Commissioners of Public Works (from 1846), and other amending and extending Acts. The primary acts were passed by the United Kingdom parliament in the years 1835 (appointing commissioners and directing a survey to be carried out) and 1839 (authorising the Shannon Navigation to be constructed). These were amended a number of times, principally in 1874.

The Shannon Navigation Act, 1874, was directed at addressing flooding and drainage issues without adversely impacting on the navigation. It led to the construction of a number of flood mitigation works, inter alia, the sluices at various weirs (Killaloe, later removed by the ESB, Meelick and Athlone), the New Cut and localised excavation. The Commissioners were provided with powers from the Drainage and Improvement of Lands (Ireland), 1863 Act for this purpose, with powers equivalent to a Drainage Board. There is a requirement to engage in the care, conservancy and maintenance of the River Shannon in the 1839 and 1874 Acts. Further changes were introduced with the Shannon Navigation Act 1990 and bylaws created under that Act.

4.3.2 Navigation Structures

To maintain levels for navigation in the main channel, WI operates a number of navigation locks. The associated control structures are inherently an obstruction to flow and their operation can, especially in the lower stages of a flood, give rise to higher upstream flood levels than would occur if the structures were not present. WI operates the sluices at each lock so as to limit the rise in upstream water levels, as far as reasonably possible.

At Meelick Weir/Victoria Lock WI's procedure for sluice operations is designed to maintain the water level upstream at Banagher between set intervals. The lower levels ensure sufficient depth for navigation; the upper levels permit the release of floodwaters.

In general, during the rising stage of a flood event the rise in upstream water level is controlled by progressively opening the sluice gates. However, once all the sluices are fully open, no further control is possible. If the flood flow continues to increase, the upstream water level will rise further and would be controlled by the fixed hydraulic characteristics of the weir structure and any adjacent floodplain flow.

Whilst Athlone Weir is owned and operated by WI, the operation of the sluices is only carried out on the instruction of ESB. Release of floodwaters from Lough Ree implies their delivery to the callows downstream of Athlone. If this release occurs late in the flood, it will worsen depths downstream but, if released early, it could worsen the duration of downstream flooding. The current ESB Regulations and Guidelines (see Section 7.5) provide a balance between these effects.

4.3.3 Lake Levels

WI's requirement to maintain levels for navigation in Loughs Allen, Ree and Derg, is achieved through the ESB's management of the lake outlet structures in accordance with the ESB Regulations. The management operations at Bellantra, Athlone Weir, Parteen Weir and Ardnacrusha are determined by ESB. For Loughs Allen and Ree, the current minimum normal operating levels vary for different seasons, although there have been several historic changes. Details of the historic changes to operating levels in Lough Ree are given in Section 7.5.

4.3.4 Navigation in General

Under the current regulations and levels, Waterways Ireland believes that the River Shannon navigation channel has sufficient depth to provide reasonable passage. Some work to remove obstacles or small rock shoals is occasionally needed at localised spots. Before maintenance or improvement is carried out WI must consult

extensively with National Parks and Wildlife Service, Inland Fisheries Ireland and the Environmental Protection Agency (EPA) if a Waste Disposal Licence is required.

4.4 National Parks and Wildlife Service (NPWS)

NPWS prepares and manages policy in relation to the natural environment, and has national and international responsibilities. One part of the international role is to ensure European Union (EU) nature conservation legislation is assimilated into Irish national policy and legislation.

Their role is to secure the conservation of range of ecosystems and maintain / enhance population of flora and fauna, where possible. Habitats include turloughs, fens (which are often sensitive to water level fluctuations) as well as lakes, rivers, bogs, and important floodplain habitats such as the Shannon callows. Among the species are wetland birds, salmon and other species of fish, and protected invertebrate species such as freshwater pearl mussel and crayfish.

The NPWS, as the key competent authority for the Birds and Habitats Directives and as the responsible body under the Wildlife Acts, has designated the Shannon Callows with three designations (SPA, SAC, NHA).

4.5 The Office of Public Works (OPW)

The OPW is the lead agency for flood risk management in Ireland and coordinates and implements government policy relating to flood risk management. Under the Arterial Drainage Acts, 1945 to 1995, OPW carries out maintenance of Arterial Drainage Schemes on river channels such as the River Brosna and other tributaries, but does not have responsibility for maintaining the Rivers Shannon and Suck. Most of the River Suck forms part of a Drainage District whose maintenance is the responsibility of Galway and Roscommon County Councils.

The OPW is also responsible for implementing and maintaining Flood Relief Schemes and provides funding to Local Authorities (subject to certain criteria) for minor flood alleviation schemes.

4.6 The Irish Farmers Association (IFA)

The Irish Farmers Association (IFA) represents many farmers in the Shannon catchment. The farmers believe that there has been a noticeable increase in flooding to their land from the Shannon over the last 20 or so years, and attribute the increase not only to a change in climate patterns, but also to the activities, or lack of activity, of other organisations. In July 2002 the IFA, on behalf of its members, drafted a set of proposals to resolve River Shannon flooding problems, some of which were addressed in the Pre-Feasibility Study (OPW, 2004).

4.7 Other Stakeholders

In addition to Waterways Ireland, a number of other stakeholders have an interest in navigation on the Shannon. These stakeholders include:

- The Inland Waterways Association of Ireland (IWA)
- The commercial bodies (boat companies) reliant on tourism on the Shannon
- IBRA (Irish Boat Rental Association)

Other stakeholders have an interest in the Shannon, but it is understood that their particular areas of concern are not directly affected by the variations in water level operations considered in this report. Such stakeholders include:

- Shannon Regional Fisheries Board
- Bord na Mona (commercial peat milling and harvesting)
- Local authorities
- Fáilte Ireland (offers tourism professionals and service providers a wide range of support services at local, regional and national levels)

5 Stakeholder Consultation

5.1 Introduction

This section summarises the input to this technical assessment received during consultation with the following stakeholders:

- Electricity Supply Board
- Waterways Ireland
- Irish Farmers Association (landowners)
- National Parks and Wildlife Services

The objectives of the consultation were to provide an opportunity for key stakeholders to:

- explain their role in the management of the Shannon and its floodplain
- indicate their understanding of the current flood risk management issues
- facilitate access to the necessary hydrometric data required for undertaking the technical assessment

5.2 Electricity Supply Board

A meeting was held at ESB offices in Dublin on 29 March 2011 during which the ESB team gave a presentation on their management of water levels on the Shannon covering:

- Overview of the River Shannon
- Severe weather event of 2009
- ESB's role in the management of water levels and the 2009 Shannon flood at Loughs Allen, Ree and Derg

Key points as presented by ESB were:

- ESB has no strategic interest in storing water in Lough Allen or Lough Ree for electricity generation
- In flood situations, the safe discharge of flood waters takes precedence over the generation of electricity
- Lough Allen reduces peak flood discharges by storing water (e.g. an additional 72 million m³ were stored in the flood of November 2009)
- ESB has no control of the level in or the discharge from Lough Ree in flood situations
- Levels in Lough Ree, Athlone and the callows downstream of Athlone can rise quickly due to rainfall and recede slowly due to the flat gradient and restricted channel capacity between Athlone and Meelick ¹
- Minimum levels on Lough Ree are only achieved in very dry summers and not in winters ²
- Water moves slowly through the Shannon system due to the low natural gradient and the restricted channel capability

¹ Water levels downstream of Athlone Weir and in the callows can also be affected by inflows from the Suck and the Brosna. See Section 9.

² The potential for modifying the Athlone Weir Operating Procedures to make more use of the available storage in Lough Ree is considered in Section 10.

ESB issue a twice weekly forecast of water levels for Loughs Allen, Ree and Derg, predicted for five days ahead. This forecast is issued on Mondays and Thursdays by email to WI, Local Authorities, OPW and other interested parties (including landowners).

5.3 Waterways Ireland

A meeting was held at the Waterways Ireland offices in Carrick-on-Shannon on 30 March 2011. WI staff outlined the historic development of the Shannon Navigation and emphasised the significant development of recreational traffic since the 1960s, with restoration of the Lough Allen canal in the 1970s, re-opening of the Shannon-erne Waterway in 1994, restored navigation access to Lough Allen in 1996, and the commissioning of Pollboy Lock on the River Suck in 2000 providing a new navigation access to Ballinasloe.

Water level data is recorded continuously at a number of locations along the Shannon. In most cases, water levels are controlled by hydraulic structures with variable limited openings and by downstream water levels, so there is no unique relationship between level and flow. The exception is at Banagher for flows above about 140 m³/s. The corollary of this is that the variable controls are insufficient to manage levels over much of the range of flows that occurs every year.

WI confirmed that the Bellantra sluices are controlled by the ESB operatives on site and that WI staff operate the sluices at Athlone Weir on instruction from ESB. Other sluices at Jamestown, Roosky, Tarmonbarry and the water level control complex at Meelick Weir/Victoria Lock are all operated under the direct control of WI.

WI outlined their operational procedures (for further details on Meelick Weir, including removal of weir boards, see Section 7.6). WI confirmed that, after the initial rise in water levels above the normal “trigger” levels, once all the controls have been utilized (i.e. all sluices open and weir boards removed) WI cannot control or reduce flooding on the river.

WI advised that users regularly now make use of the navigation through to the October Bank Holiday (the last Monday in October), although there has been no change to the operating levels associated with increasing navigation use. WI emphasised the importance of ensuring water levels in Lough Ree did not fall beneath the required Minimum Normal Operating Level to ensure the full safe navigational area in dry summers.

5.4 Irish Farmers Association

A meeting was held with representatives of the Irish Farmers Association in Athlone on 20 April 2011. Salient points from this meeting relevant to this Level Operations Report are as follows:

- The most vulnerable area is on both banks between Athlone and Banagher and which is subject to extreme regular flooding. This issue has been regularly discussed by the IFA with various bodies and while the IFA feel they have been listened to no action has been taken to alleviate the problem. Flora and fauna is also affected in the area. Flooding is generally as a result of the land being low lying but the IFA consider that flooding in some places is caused by the operation of control structures on the River Shannon. The

IFA feel that Waterways Ireland and maintenance of navigable channels takes precedence over farmers' needs.

- Athlone Weir - today water constantly spills over the weir at high flow rates, in the past the weir top was visible. The question was raised as to why this is. The IFA believes that the gates should be opened to increase the storage capacity of Lough Ree in times of flood risk to save the callows from severe flooding, particularly summer flooding which is the IFA's main point of concern. Generally the IFA accept that farmland within the floodplain is liable to flooding in the winter; it is summer flooding and any flooding potentially exacerbated by the operation of control structures on the River Shannon that is the main cause for concern.
- In the 1970s the Shannon forum was approached by those with interests in navigation improvements and asked for a 150mm raise in water levels from May to October. The IFA believe level was actually raised by 600mm; this level should be reduced to the pre-1970s level.
- The issue of siltation in the Shannon was raised and discussed. The IFA believe that Bord na Mona have been allowing silt to enter the Shannon unchecked for decades and should be held accountable for this and forced to remove the silt from the river. IFA believe that getting into the region to remove silt and trees from the river channels will reduce the flood risk. The IFA have attempted to do this in the past but have been met by constant unreasonable resistance from the NPWS. The IFA believe the NPWS rationale to be flawed as the flooding causes much more damage to the environment than river channel maintenance. One particular example is the Corncrake which, on the Shannon, is dying out due to flooding.
- The IFA reiterated that they don't mind winter flooding to a standard normal level; however they don't want flooding of houses any time of the year. In summer the IFA believe that managing the lakes will stop flooding which is the main issue for the IFA.

This meeting therefore confirms that the main outstanding issues from the proposals drafted in July 2002 and reported in the Pre-Feasibility Study (OPW, September 2004 - see Section 2.1.2) are:

- The density and extent of riverside and in-channel vegetation has increased dramatically over the last twenty years, and that the Office of Public Works should identify the areas where remedial work can be carried out on the main channel to keep it open.
- Bord na Mona has contributed to heavy siltation in the river and the siltation has led to a reduction in capacity of the channel to carry floodwaters.
- There are a number of issues with the weir at Meelick, principally that it is an obstruction to flow. A number of remedies are suggested including review of its operation in floods, removal of residue from the weir and installing more sluices.

- The operational arrangements on Lough Ree (at Athlone Weir) and at the navigation locks are not satisfactory; the sluices could be managed more effectively to reduce flooding.

5.5 National Parks and Wildlife Service (NPWS)

NPWS is a Statutory Authority and will be consulted thoroughly through the delivery of the Shannon CFRAM Study. NPWS confirmed they would welcome the opportunity to discuss specific issues related to the Shannon CFRAM Study, once they are in receipt of the Shannon SEA Scoping Report to ensure they have sufficient background knowledge on the project to allocate necessary resources to the specific issues.

6 Hydrometric Data

6.1 Introduction

River levels on the Shannon have been monitored in some form for well over 150 years. Intermittent records at some of the navigation structures may have been maintained but no records prior to 1932 have been made available for this study, other than a few examples quoted in some previous reports (eg highest recorded levels in the January 1925 flood at Lough Allen and Lough Derg).

Relevant data is maintained by at least three separate organisations: Electricity Supply Board (ESB), Waterways Ireland (WI) and The Office of Public Works (OPW). In some cases it appears that separate records are maintained by the different organisations for what, from a hydrometric perspective, would be expected to be the same (or very similar) location. For instance, daily upstream water levels at certain locations (eg Athlone Weir) have been provided by both ESB and WI, with daily mean level data also available from OPW for some periods.

We have carried out a few spot checks where data is available from more than one source. Some minor differences and potential inconsistencies are evident in these records. However, for the purposes of this report we consider these minor differences not significant, generally being of the order of a few cm at most. We have not therefore attempted to resolve these minor issues which may be related to a number of factors, including:

- Time of day when level is recorded: ESB has confirmed that daily levels are recorded at 0900 hrs.¹ WI data we understand is also recorded at 0900 hrs (or possibly 1000 hrs in some instances). OPW data where available is mean daily level, presumably derived from the 15 minute data at autographic recorders. In general, because of the relatively slow response of the Shannon due to the size of the catchment and the attenuation effect of the large lakes, the impact of differences in timing on levels recorded is relatively minor, other than perhaps on the rising limb of a large flood event.
- Precise location of the recording gauge, with the potential for some hydraulic gradient between locations, at least at high flows.
- Datum adopted for the gauge zero. Although all levels are quoted to mOD Poolbeg, there appear to be some small differences between the records.
- Gauge boards historically read in Imperial units (probably to the nearest inch) and subsequently converted to metric units.

Overall, we are satisfied that the records we have adopted (generally those with the longest or most complete timeseries) for our analysis provide an adequate basis for this review of level operations on the Shannon.

6.2 ESB Data

ESB provided a time series of daily levels, flows and rainfall, generally over the period 2 January 1932 to 8 May 2011, as indicated in Table 6.1.

¹ The ESB data file provided suggests the levels are recorded at 1500 hrs after 31/12/1969 but ESB has advised that this is just a time stamp in the data file.

A number of queries on the dataset originally provided by ESB were raised by Jacobs on 18 May 2011. A revised dataset with some further explanation was provided by ESB on 29 May 2011.

Table 6.1 ESB Daily Time Series Data

Location	Comment by Jacobs
Lough Allen Upper Level (mOD)	Only from September 1937
Lough Allen Lower Level (mOD)	Only from September 1937
Athlone Upper Level (mOD)	
Athlone Lower Level (mOD)	
Victoria Lock Upper Level (mOD)	
Victoria Lock Lower Level (mOD)	
Portumna Level (mOD)	
Killaloe Upper Level (mOD)	
Parteen Upper Level (mOD)	
Parteen Lower Level (mOD)	
Lough Derg Inflow (m ³ /s)	Presumably calculated from Parteen Total Discharge and storage change in Lough Derg
Parteen Total Discharge (m ³ /s)	Includes flow through Ardnacrusha Power Station as well as sluices at Parteen Weir
Banagher Rainfall (mm)	Only from October 1991

Note: Rainfall data not used in the analysis for this report.

ESB provided a copy of a Preliminary Report dated May 2011 (Athlone Weir Discharge Equations – Revision of October 2010). This report considered the impact of four additional flow measurements (over the range 265 – 380 m³/s) carried out in November 2009 as part of the Hydrometric Activities undertaken by the Environmental Protection Agency. The report concluded that:

- there was no strong case for replacing the equations developed in 2006 (which itself took account of 10 additional flow measurements since an initial review following the 1994/95 flood based on the 7 available flow measurements at that time).
- the Athlone discharges estimated by these equations are a significant improvement on those estimated using the equations in the document *Regulations and Guidelines for the control of the River Shannon* (ESB November 2003).

The ESB discharge equations for the sluices take account of the full range of downstream water levels, and thus of the influence of Suck and Brosna inflows where relevant.

A complete timeseries for flows at Athlone based on these equations has not been available for this study. For a number of periods over which records of Athlone Weir gate operation were available and for the purposes of this report, we have calculated flows at Athlone based on the equations provided in the ESB May 2011 Preliminary Report, the ESB records of Upper and Lower water levels and the Waterways Ireland records of gate openings.

6.3 Waterways Ireland Data

Waterways Ireland prepare daily reports of water levels at various locations as indicated in Table 6.2. These reports are collated into annual datasets. Datasets were provided for years 1987 to 2010 in digital format as attachments to a series of emails on 20 May 2011. However, not all data is available for all years (eg data from the relatively new Pollboy Lock only available from 2001).

Table 6.2 Waterways Ireland Daily Time Series Data

Location	Level	Rainfall	Sluice Openings
Drumshanbo (Lough Allen)	x		
Clarendon Lock Upper Level	x		
Clarendon Lock Lower Level	x		
Jamestown Sluices	x		x
Albert Lock Upper Level	x	x	
Albert Lock Lower Level	x		
Roosky Lock Upper Level	x	x	x
Roosky Lock Lower Level	x		
Tarmonbarry Lock Upper Level	x	x	x
Tarmonbarry Lock Lower Level	x		
Lough Ree	x		
Athlone Lock Upper Level	x	x	x
Athlone Lock Lower Level	x		
Pollboy Lock Upper Level	x	x	
Pollboy Lock Lower Level	x		
Banagher	x	x	
Victoria Lock Upper Level	x	x	Meelick and New Cut
Victoria Lock Lower Level	x		
Portumna Bridge	x	x	

Notes: Rainfall data not used in the analysis for this report.

'x' denotes information is available.

'x' under Sluice Openings indicates a daily record of actual sluice openings is available

6.4 OPW Hydrometric Data

Mean daily level and flow data has been extracted from the on-line OPW hydrometric database "Hydro-Data", supplemented by some more recent data provided directly by OPW. Details of the records considered for use in this study are given in Table 6.3.

Table 6.3 OPW Daily Time Series Data

Station	Level	Flow
25011 Moystown (Brosna)	not required for this study	01/01/87 to 10/09/10 (major gap 2004-2007)
25006 Ferbane (Brosna)	not required for this study	01/02/72 to 10/09/10 (major gap 2005-2008)
25017 Banagher	01/12/89 to 14/06/10	01//02/89 to 20/04/10 (only where flow > ~150 m ³ /s)
26007 Bellagill (Suck)	not required for this study	02/01/75 to 13/06/10 (major gap 2003-2007)
26027 Athlone d/s	01/02/72 to 14/06/10	n/a
26028 Shannonbridge	01/02/83 to 10/02/10	n/a
26329 Athlone Intake	n/a	n/a
26333 Athlone Weir u/s	22/10/03 to 30/08/07	n/a

There are a number of other OPW stations on the Shannon. However, this report focuses on the flood risk affected by the operation of Athlone Weir, particularly the callows area between Athlone Weir and Banagher. The data listed in Table 6.3 is relevant for this reach.

In view of the relatively slow response of the Shannon to rainfall, for the purposes of this study we have not considered the 15 minute level and flow data where this is available.

7 Current Operating Procedures

7.1 Introduction

The objective of this section is to provide an overview of the current operating procedures for the water level control structures on the Shannon between Lough Allen and Limerick. Details are provided for the structures controlling separate reaches as follows:

- Bellantra Sluices and Lough Allen
- Upper Shannon Weirs
- Athlone Weir and Lough Ree
- Meelick and New Cut Sluices
- Parteen Weir, Ardnacrusha Power Station and Lough Derg

We provide an assessment of the extent to which the operating procedures for each of these reaches potentially has an impact on the issues of flood risk management. Particular focus is given to possible impact in the callows area between Athlone and Banagher which, as noted in Section 5.4, is of primary concern to the IFA.

7.2 Overview

The current operating procedures for the principal control works on the Shannon remain essentially as defined in the Electricity (Supply) Act, 1927 and subsequent amendments. Responsibility for determining the operation of the structures which control the three major lakes (Loughs Allen, Ree and Derg) lies with ESB, in accordance with the current version of the document *Regulations and Guidelines for the Control of the River Shannon* (ESB November 2003, with minor revisions in 2008).

The control structures are at the outlets to these three lakes, as follows:

- Bellantra Sluices on Lough Allen;
- Athlone Weir controlling the outflow from Lough Ree; and
- Combination of Parteen Weir and Ardnacrusha Power Station controlling the outlet of Lough Derg.

Consultation with ESB confirmed that Athlone Weir is primarily designed to maintain minimum levels in Lough Ree. Bellantra Sluices and the Parteen Weir/ Ardnacrusha Power Station complex, as well as maintaining minimum levels, also facilitate the management of floods in Lough Allen and Lough Derg respectively.

Waterways Ireland is responsible for the operation of sluice structures in weirs at four other locations: three on the Upper Shannon at Jamestown, Roosky and Tarmonbarry; and two sets of sluices in parallel river channels in the vicinity of Victoria Lock between Lough Ree and Lough Derg (at Meelick Weir, near Keelogue, and at Marlborough Weir on the New Cut). Under low flow conditions weir boards are installed on Meelick Weir to maintain upstream water levels.

The operation of sluices at these four locations is intended as, far as possible, to maintain water levels in the upstream reach within a narrow range. Once flows in the river rise above a certain level and all the sluices are fully open, Waterways

Ireland has no control over water levels, which will continue to rise as the flow over the weirs increases.

7.3 Bellantra Sluices and Lough Allen

The current sluices at Bellantra were installed by ESB in the 1930s to increase the control over Lough Allen, primarily so that low flows on the lower Shannon could be augmented from upstream storage for the benefit of hydropower generation at Ardnacrusha.

The *Regulations and Guidelines for the Control of the River Shannon* (ESB November 2003, section 2.7.2) state:

“Optimisation of storage from Lough Allen is no longer a factor of importance to ESB in the generation of power at Ardnacrusha. As a result of discussions between ESB, the local farmers and Community interests in the Lough Allen area, the ESB endeavours to maintain the level of Lough Allen above 48.16 mOD between mid-March and the end of October. To achieve this it is desirable that the level of the lake is above 48.60 mOD during May and early June, as the minimum required discharge at Bellantra of 5.0 m³/s exceeds the average summer inflow to the lake.

In general, when there is no flood only the minimum discharge (5m³/s) is released from about the beginning of June or earlier to endeavour to achieve the above aspiration.

During the remainder of the year a discharge of 20-25 m³/s is generally sufficient to keep the lake level at or about 49.68 mOD (Maximum Normal Operating Level). However, a level of 47.50 mOD in the river downstream of the sluices corresponding to a discharge of about 30 m³/s is within the designed capacity of the channel and does not cause any flooding or water-logging of lands adjacent to the river. It is to be noted that a downstream level of about 48.0 mOD, (corresponding to a discharge of 45 m³/s), causes some waterlogging but no flooding of lands.

In general, when the water level is approaching 48.90 mOD, the discharge from Lough Allen should be set to match the inflow, subject to the bottom leaf opening of each gate not exceeding 0.4m. This is considered to make best use of the available storage in Lough Allen for flood purposes, taking account of all other user interests.”

At a meeting on 29 March 2011 ESB provided the following summary of operating procedures for Lough Allen:

Non Flood Periods (Water Level < 49.68mOD)

Lake level maintained below 49.00mOD by adjusting gates.

This ensures min navigation level in most dry years.

Flood Periods (Water Level > 49.68mOD)

2 bottom leaves of sluice gates set at opening of 0.4m. Top of upper leaves set at 49.68 mOD.

As water level increases above 49.68 mOD discharge increases gradually.

We have analysed the recorded Lough Allen water level data for the 2009 flood event and we can confirm that there was a 2.04 m rise in water level from a minimum of 48.73 mOD on 17 October to a peak of 50.77 mOD on 22 November. This rise in water level represents a total storage volume of 72 million m³ based on a lake area of 35.2 km². Once the final sluice adjustment had been made on or soon

after 17 October, the fixed hydraulic characteristics mimic the attenuating effect of a natural lake, and generally reduce peak flows and hence levels downstream compared with what would have occurred in the absence of the storage effect.

The daily flows downstream of Bellantra Sluices (gauging station ref 26030) from the EPA Hydronet website show that the peak daily outflow was $58 \text{ m}^3/\text{s}$ on 20 November, with a peak daily mean level of 48.525 mOD. Based on this dataset and taking a mean of the ESB (Bellantra) and WI (Drumshanbo) recorded daily levels for Lough Allen, we estimate that the inflow to Lough Allen exceeded $90 \text{ m}^3/\text{s}$ over the four days 16 to 19 November. The estimated peak daily inflow to the lake on 18 November of almost $100 \text{ m}^3/\text{s}$ was well in excess of the subsequent peak outflow of $58 \text{ m}^3/\text{s}$, demonstrating the attenuating effect of the lake.

During our consultation exercise, information was gathered regarding comments by some members of the public that the discharge at Lough Allen was increased suddenly in the early morning of 25 November 2009 which resulted in a sudden rise in water levels in Leitrim village. We have analysed the 15 minute water level records from EPA gauging station 26030 which is located just downstream of Bellantra Sluices – see Figure 7.1. The maximum recorded rise over a 30 minute period was only 0.012m, from 20:45 to 21:15 on the 24 November 2009; this represents an increase in discharge of less than 1% on a flow of about $54 \text{ m}^3/\text{s}$. This analysis of the recorded water level data suggests there was no sudden increase in discharges at Bellantra Sluices during the night of 24-25 November 2009.

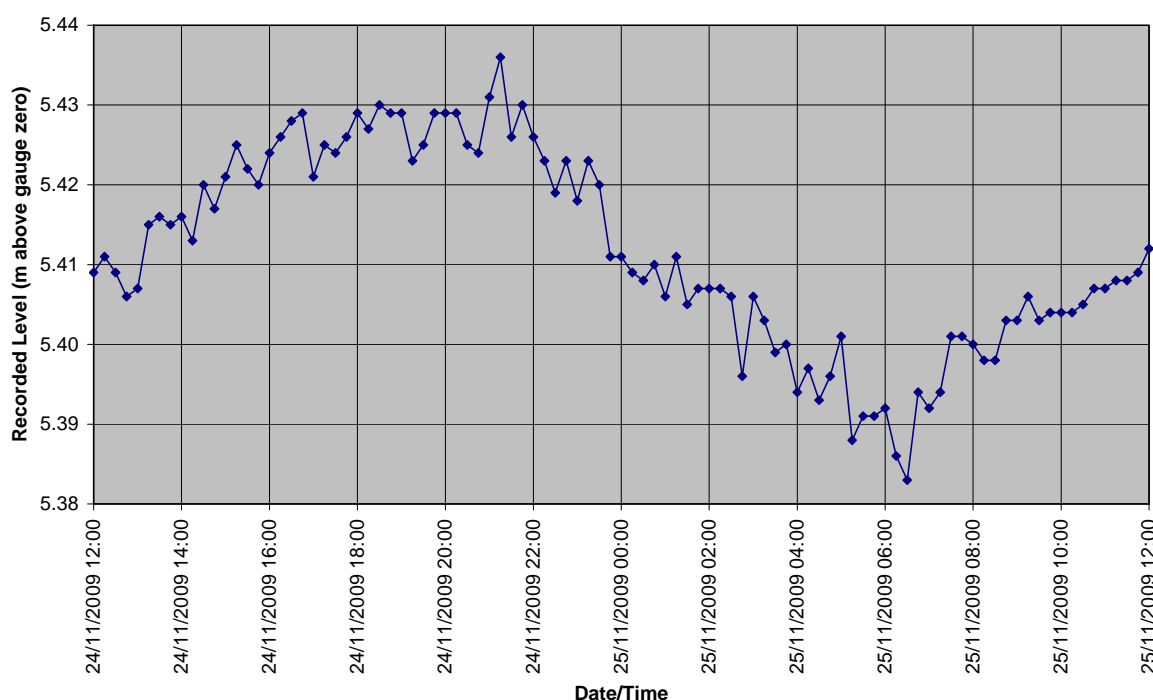


Figure 7.1 Level Variation recorded at EPA Gauge 26030 downstream of Bellantra Sluices 24-25 November 2009

We are not aware of any other significant concerns regarding the current operating procedures for Lough Allen. As the Bellantra sluices control less than 10% of the Shannon catchment at Athlone and with a lake around one third of the area of Lough Ree, it is unrealistic to suggest that modification of these procedures could have any material impact on water levels either in, or downstream from, Lough Ree.

No further consideration has therefore been given in this report to water levels in Lough Allen.

7.4 Upper Shannon Weirs

The Jamestown Sluices are operated by Waterways Ireland to control water levels in the reach upstream, including three small lakes: Lough Corry on the Shannon and Loughs Drumharlow and Oakport on the Boyle River tributary. Similarly the weir and sluices at Roosky control water levels in the river channels and in several small lakes, primarily Loughs Bofin and Lough Boderg on the Shannon. Tarmonbarry weir and sluices controls water levels in the river channel and in the small Lough Forbes.

As indicated in Section 7.2, during flood conditions the sluices on all these weirs are fully open and there is no control over water levels other than the fixed hydraulic characteristics of the structures.

We have examined the WI water level and sluice opening records for 2007 and can confirm that all 12 sluices at Jamestown and Roosky were opened on the four occasions in 2007 when water levels rose above the “normal” range. This confirms that there is little if any scope for managing flood levels upstream of Lough Ree.

During the consultation for this report, no concerns were raised regarding the current operating procedures for these structures. As there is minimal storage relative to that available in Lough Ree downstream, and no facility to modify the hydraulic characteristics during flood events, it is unrealistic to suggest that modification of the operating procedures could have any material impact on water levels either in, or downstream from, Lough Ree.

No further consideration has therefore been given in this report to water levels upstream of Lough Ree.

7.5 Athlone Weir and Lough Ree

Athlone Weir controls the outflow from Lough Ree. The weir was re-surveyed in Summer 1994 and has an average crest level of 37.40 mOD. The overall structure consists of four principal elements¹:

- a) navigation lock on the right bank
- b) small weir length 10.59m
- c) 15 No. Gates 1.91m wide (invert level 35.51 mOD; when closed 37.40 mOD) - in groups of three; each group divided by piers 0.9m wide (6 No.) - each gate divide approx. 75mm
- d) large weir length 174.41m (incl. fish pass 0.915m wide @ 36.78 mOD)

¹ Data taken from ESB Preliminary Report, May 2011, Athlone Weir Discharge Equations – Revision of October 2010

The structure is owned and operated by Waterways Ireland but the sluices are operated in response to instructions from ESB.

The *Regulations and Guidelines for the Control of the River Shannon* (ESB November 2003, sections 1.5.3 and 2.7.3) state:

“1.5 FLOOD OPERATIONS

1.5.3.1 General

Generally, flooding downstream of Athlone results in the inundation of large areas of agricultural land. The maximum flood level recorded downstream of Athlone Weir over the past 75-80 years was in December 1954 when the level reached 38.55 mOD. [Note: This level was subsequently exceeded in December 2006 (38.57 mOD) and November 2009 (39.05 mOD).]

1.5.3.2 Flood Management

In order to minimise flooding below Athlone, the sluice gates must be kept closed for the duration of the flood.

Summer Period

When floods occur in the period 1st April to mid-October, then all sluices should be closed when the level downstream of Athlone Weir rises above 36.12 mOD on the gauge, and kept closed until the flood recedes. When the level has again dropped below 36.12 mOD the sluices may be gradually opened so long as the water level remains below 36.12 mOD.

Winter Period

When floods occur between mid-October and 1st April, the sluice gates should be closed when the downstream level reaches 36.42 mOD on the gauge. They should be kept closed until, on the recession of the flood, the level drops below 36.42 mOD

2.7 ROUTINE OPERATIONS

2.7.3.1 General

The sluices at Athlone are operated so as to augment low flows downstream of Athlone Weir, but this facility is used only during periods when there is no problem of flooding or waterlogging between Athlone and Meelick and subject also to the provisions relating to:

(a) Minimum flow (See Appendix C)

and

(b) Low levels in Lough Ree (See Appendix C)

Observations have shown that water-logging of the callows below Athlone commences when the level of the downstream gauge reaches 36.12 mOD. Flooding commences when the level reaches 36.42 mOD approximately. (Tolerance of ± 75 mm is acceptable). Water-logging is not a problem in the winter months but should be prevented as far as possible in the summer period.

2.7.3.2 Guidelines of Discharge during non-Flood Periods

The following Guidelines are suggested for water levels in Lough Ree subject to 1.5.3.2, 2.7.3.1 and 2.7.3.3.

- Between April and June, if the level in Lough Ree is above 37.80 mOD, then open the sluices at Athlone gradually to lower the lake level to 37.65 mOD.*
- Between July and mid- August, if the level in Lough Ree is above 37.70 mOD, then open the sluices at Athlone gradually to lower the lake level to 37.55 mOD by the end of August.*

The foregoing optimises storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years.

- *To optimise storage in Lough Ree from mid-August to October, sluices should be operated to reduce the level in Lough Ree to 37.19 mOD by mid-October provided downstream levels permit. All as per Clauses 1.5.3.2 and 2.7.3.1.*

2.7.3.3 Low Lake Levels

If the water level upstream of Athlone falls below 37.49 mOD, then the sluices must be operated in accordance with the Standing Instructions outlined in Appendix C.

2.7.3.4 Navigation in Lough Ree

The minimum navigation level in Lough Ree is 36.88 mOD. However, in recent years with the growth in pleasure cruising and the use of larger boats, lowering of the lake to this level greatly reduces the safe navigational area. Accordingly, in 1979 the Board agreed that it would endeavour to restrict the drawdown of Lough Ree to 37.49 mOD until mid-August and to 37.19 mOD until 1st October. This had already been applied informally since 1972. In an emergency the level can of course be drawn down to 36.88 mOD and further to 36.27 mOD by prohibiting navigation.

Navigation between Athlone and Tarmonbarry must be prohibited when the water level in Lough Ree falls below 36.88 mOD.

When drawing below 36.88 mOD the Board must first approve a special order prohibiting navigation in the river above Athlone. This order must be published in the daily papers and exhibited in poster form at all navigation offices along the river, for as long as possible before the lowering takes place. Details of the format of the notice are given in Appendix D”.

“APPENDIX C - STANDING INSTRUCTIONS WHEN DISCHARGING FROM LOUGH REE AT LOW LAKE LEVELS

- 1. When the water level upstream of Athlone Weir falls below 37.49 mOD - two sluices should be kept open 0.91m each in order to maintain a flow to keep the river fresh for the water supply to Athlone etc. subject to Section 2.7.3 of this document.*
- 2. When the lake is being drawn down towards the minimum navigation level of 36.88 mOD, the level upstream of Athlone Weir may be allowed to drop to 36.80 mOD. In such a case, the sluices should be regulated to keep the upstream level as near as possible to 36.80 mOD, subject to the lake level not dropping below 36.88 mOD.*
- 3. When the upstream level is at about 36.80 mOD, the sluice gates may be closed temporarily to facilitate the passage of boats through the lock.*

The sluice-keeper at Athlone is responsible for ensuring that these standing instructions are implemented.”

As indicated in the ESB Regulations and Guidelines quoted above, waterlogging and flooding in the area of the callows between Athlone Weir and Meelick is a key aspect which has raised repeated concerns over the last 150 years. Subsequent sections of this report therefore focus on this reach of the river.

The extent to which Athlone Weir can be used to control levels in and outflows from Lough Ree is limited by a number of factors. ESB Regulation 1.5.3.2 precludes opening of the sluices when downstream levels exceed 36.12 mOD during the summer period or 36.42 mOD during the winter. The analysis presented in Section 9 of this report shows that, on the recession of a flood during the summer period, the downstream water level only drops below the critical 36.12 mOD level ,when the

total gauged inflow to the callows drops to about 90-100 m³/s. Allowing for inflows to the callows from the Suck and the Brosna this typically corresponds to flows over Athlone Weir of 70-80 m³/s. Hence flows which permit releases through the sluices can only occur when the upstream level drops below about 37.80-37.85 mOD due to the fixed hydraulic characteristics of the weir and sluice structures, details of which are summarised in Table 7.1. A graphical representation of these hydraulic level-discharge relationships is provided in Appendix B.

Table 7.1 Athlone Weir Hydraulic Characteristics

Athlone Weir upstream level (mOD)	Approx total discharge at Athlone Weir depending on no. of sluices open (m ³ /s)				Comment
	0	5	10	15	
36.8	0	35	46	59	fish pass crest is at 36.78 mOD
37.4	0.5	40	55	70	crest level of main weir is at 37.4 mOD but fish pass allows a small overflow
37.6	24	53	71	83	downstream level likely to exceed 36.12 mOD with 15 sluices open
37.8	66	86	n/a	n/a	downstream level likely to exceed 36.12 mOD with 5 sluices open
38.0	121	n/a	n/a	n/a	
38.2	187	n/a	n/a	n/a	
38.4	261	n/a	n/a	n/a	
38.6	342	n/a	n/a	n/a	

- Notes:
1. Discharge calculations based on ESB Preliminary Report, May 2011, Athlone Weir Discharge Equations – Revision of October 2010.
 2. Downstream water level assumed based on an approximate relationship with gauged total inflow to the callows and assuming 25% of this is contributed from the Suck and the Brosna (see Section 9.3).

Typically for flows in the range 70-80 m³/s the level of Lough Ree will be around 37.9 - 38.0 mOD. Hence discretionary control of the level of Lough Ree can generally only be achieved when the level drops below about 37.9 mOD. This explains why water levels often have to remain above this level during the early summer period. The lake level is controlled by the ability of the fixed hydraulic characteristics of Athlone Weir (which effectively mimics the outlet of a natural lake) to discharge both the lake inflow and the slow release of water from natural winter storage. Details of the drawdown pattern for Lough Ree in the summer period of recent years are shown in Figure 9.7.

7.6 Meelick and New Cut Sluices

Below Athlone Weir two major tributaries, the River Suck and the River Brosna, join the Shannon above the next set of level control structures. These structures are located on three parallel channels: Victoria Lock on the central navigation channel, Meelick Weir and sluices (a total of 12) near Keelogue on the main river channel to the west and the Marlborough sluices (a total of 18) some distance upstream on the New Cut channel to the east. These structures are all under the direct control of Waterways Ireland.

The *Regulations and Guidelines for the Control of the River Shannon* (ESB November 2003, sections 1.5.4 and 2.7.4) state:

“1.5 FLOOD OPERATIONS

1.5.4 Meelick Weir

Meelick Weir is under the control of Waterways Ireland.

On the approach of a flood, the upstream level at Meelick is lowered to 35.04 mOD and maintained at this level as long as possible subject always to the level at Banagher not dropping below 35.33 mOD. The reduction in the level at Meelick tends to increase the discharge in the river at the onset of a flood.

The level at Meelick is maintained at 35.04 mOD until all sluices at Keelogue and New Cut are fully open. Thereafter the level rises above 35.04 mOD the final level reached being dependent on the size of the flood. The maximum level recorded upstream of Meelick Weir since the commissioning of Ardnacrusha Power Station was 35.98 mOD in December 1999. [Note: This level was subsequently exceeded in November 2009 (36.41mOD).]

2.7 ROUTINE OPERATIONS

2.7.4 Meelick Weir

The control works at Meelick are comprised of a fixed overflow weir and sluices at Keelogue, and the New Cut Sluices which are situated on a side channel about 1.7km upstream of Keelogue. The level of the weir can be raised by 0.38m by the insertion of weir boards. The works are under the control of the Waterways Ireland.

During periods of low flow the works at Meelick are regulated to maintain a minimum level for navigation upstream of Keelogue Weir. The determining level for good navigation conditions in the river up to Athlone is a minimum level of 35.33 mOD¹ at Banagher gauge which is approximately 8km upstream of Meelick. The sluices at Keelogue and the New Cut are regulated by Waterways Ireland to ensure that the level at Banagher does not fall below 35.33 mOD, subject to a minimum level of 35.04 mOD upstream of Keelogue Weir.

During low flow the weir boards are normally placed in position to maintain the navigation depth upstream of the weir. As flows increase the weir boards are gradually removed.”

Waterways Ireland has stated² the current operating procedures for Meelick Weir and the New Cut Sluices as follows:

“The weather forecast, the six day rainfall forecast from Met Eireann for the Shannon area upstream, and the ESB’s twice weekly predictions for the levels of Lough Allen and Lough Ree are taken into account: if the gauge level at Banagher is at 2.13m³ and the forecast is for heavy rainfall, sluices are opened in anticipation of heavy rainfall. However, at times the rain does not materialize or can fall outside the Shannon catchment. Waterways Ireland monitor and operate the sluices throughout

¹ “This level was revised in 1990 - from 35.40 to 35.33 mOD following agreement between Waterways Ireland, the farming community and boating interests.”

² *Water Level Control on River Shannon between Athlone and Meelick*, WI, March 2011

³ 2.13m on the Banagher gauge is equivalent to 35.37 mOD. The WI operating procedures endeavour to keep the water level at Banagher between 2.08m and 2.18m – i.e. 35.32 to 35.42 mOD. The 35.32 mOD minimum figure is marginally different from the 35.33 mOD figure quoted in the ESB Regulations.

the working week and have personnel on call at weekends and on Public holidays both to monitor the levels and operate the sluice if necessary.

The level at Banagher is monitored throughout the day if heavy rainfall is expected and alterations made to the controls as necessary.

The personnel are not on call during the winter or during flood periods when a high level has been established and all the sluices are open and weir boards removed.

At this stage there is nothing that Waterways Ireland can do to control water levels.

As winter floods recede, Waterways Ireland allows the level at Banagher to fall to normal summer level. Once it reaches summer level, Waterways Ireland commences opening/closing sluices to maintain the level within the operating range of 2.08m to 2.18m on the Banagher Gauge¹. When the point is reached where there are only three to five gates still open, the weir boards are put in place. The decision to install the weir boards is taken in the light of the weather forecast and catchment conditions. Once in place, the weir boards normally remain in place for the summer season.

As the level rises, the sluices are opened to keep the level in the Shannon within the range of 2.08m to 2.18m. When there are only three to five sluices left to open, the weir boards are taken out. The decision to remove the boards is taken in the light of the weather forecast and catchment conditions, ie soil saturation².

The daily operation procedure is as follows:

- IV. Daily readings of water levels at Banagher and nine points upstream of it are taken as well as rainfall readings at Banagher and 5 locations upstream of it.*
- V. The weather forecast is taken into account. This is obtained from the Met Eireann website. Every morning the weather forecast from the website is printed off and this, along with the readings referred to in (I) above, inform decisions made with respect to the operation of the controls at Meelick. The Met Eireann forecasts are filed with the rainfall and level readings. The ESB's twice weekly predictions for the levels of Lough Allen and Lough Ree are taken into account.*
- VI. A decision is made as to what changes, if any, are to be made to the controls at Meelick. This decision is made based on the following:*
 - a) Banagher level and downstream level at Athlone Lock*
 - b) Actual rainfall upstream*
 - c) Water level upstream*
 - d) Weather forecast and ESB twice weekly predictions for levels of Lough Allen and Lough Ree are taken into account.*

This decision is based on experience gained from operating the sluice over many years. The day to day decisions on the controls are made by the engineer based on the advice of the foreman and the available data."

From the foregoing it can be seen that as flows and water levels increase above normal summer levels, Waterways Ireland progressively open sluices at both Meelick (12 No.) and on the New Cut (18 No.) and remove any weir boards which have been in place. Examination of the WI records of sluice openings and

¹ The purpose of the operating range is to provide the necessary operational flexibility and facilitate a practical limit to the frequency of sluice and weir board operations.

² WI advise that river levels in both the Suck and Shannon prior to the rainfall event are taken as an indicator of the soil saturation. If the river level is low, the water table is low whereas if it is near the flooding level, the rainfall will have a greater effect on runoff.

comparison with level records at Athlone over the summers of 2007 to 2010 (see Section 9) confirms that the periods when all 30 sluices were fully opened coincides almost exactly with periods when the downstream level at Athlone exceeds the 36.12 mOD “trigger” level for potential waterlogging of the callows.

Concern has been expressed that the stated procedure for taking out of the weir boards “*When there are only three to five ... of the 30 sluices left to open*” seems a bit late to remove the boards. The WI data sheets provide specific details of daily sluice openings but not of insertion/removal of the weir boards. Further details of weir board removals were provided by WI for recent summer flood events as shown in Table 7.2.

Table 7.2 Details of WI operations at Meelick Weir during Summer Floods

Year	Key dates				Comment
	All 30 sluices fully open from	Weir boards removed	36.42 mOD downstream level at Athlone	Peak level in callows (see Note below)	
2007	12/07	30 on 12/07 85 on 13/07	14/07	29/07 (36.83mOD)	Weir boards removed 1 day after sluices fully opened but 1 day before onset of flooding level reached and 15 days before peak level reached
2008	10/08	All 115 on 11/08	16/08	18/09 (37.56 mOD)	Weir boards removed 1 day after sluices fully opened but 5 days before onset of flooding level reached and 37 days before peak level reached
2009 (early summer)	10/04-03/06 (except for 2 sluices closed at Meelick on 23/04)	None inserted until after 22/06	26/04	21/05 (36.94 mOD)	No weir boards installed prior to this event
2009 (late summer)	16/07 until 08/08 inclusive and from 19/08	51 on 19/07 64 on 20/07	Max 36.36 mOD on 29/07. 36.42 mOD not reached until second rise in levels on 21/08	30/07 (36.27 mOD) 05/09 (37.57 mOD)	Weir boards removed 4 days after sluices fully opened but 9 days before peak of initial level rise and 37 days before peak level reached on 05/09
2010	1200 hrs on 07/09	All 115 by 1500 hrs on 07/09	11/09	25/09 (36.78 mOD)	Weir boards removed 2 hours after sluices fully opened but 4 days before onset of flooding level reached and 18 days before peak level reached

Note: As represented by the average of the downstream levels at Athlone and Pollboy Lock and that recorded by OPW at Shannonbridge

Our analysis of the 5 recent flood events presented in Table 7.2 shows that the period from when all sluices at Meelick and the New Cut were fully opened and all weir boards removed to the time when peak water level in the callows was reached varied from a minimum of 10 days in July 2009 to as many as 38 days during the

double peak event in August-September 2008. We are therefore confident that if removal of the weir boards is delayed by a few days (as appears to have happened during the relatively slow rise to the initial and lesser of the two peaks in July - September 2009) this would have no impact on either the eventual flood peak or its duration.

Hence we confirm the conclusions of previous reports that sluice operation at Meelick and the New Cut have no adverse impact on flooding in the callows, provided Waterways Ireland operate the sluices and remove the weir boards in accordance with the normal procedures.

It has been suggested that storage effects in the section of the river between Athlone and Meelick should be examined, and also of the effects of the apparent intermediate control at Madden's Island (also known as Counsellor's Ford), near Esker downstream of Banagher. Several different scenarios are possible which lead to water levels at Banagher being maintained in the target range, but which lead to different storage scenarios in Lough Ree. These include: no weir boards in at Meelick, sluices open at Athlone and Meelick / New Cut - this tends to the minimum level for Lough Ree and a low level at Banagher; weir boards in at Meelick, compensation flow only below Athlone - this tends to a higher level in Lough Ree and a variable level at Banagher.

Examination of such storage effects and other local controls between Athlone and Meelick would require the use of a suitable hydraulic model which will not be available through the CFRAM Study until 2013, at the earliest. However, from our analyses for this Report we are satisfied that, whilst such effects may be of some significance at low flows, the likelihood of them any impact on either the eventual flood peak level in the callows, or the duration of the flood, is very small.

A summary of the approximate overall hydraulic characteristics of the Meelick Weir complex is presented in Appendix B in the form of a graphical representation of level-discharge relationships with and without the weir boards in place and with a variable number of sluices open. This confirms that the variable controls have sufficient capacity to maintain the target upstream level of 35.04 mOD during floods for flows up to 150 m³/s. For flood flows above this the upstream water level will rise, although the water levels experienced upstream at Banagher and in the callows will then be largely controlled by the natural channel restrictions between Banagher and Meelick Weir.

7.7 Parteen Weir, Ardnacrusha Power Station and Lough Derg

Since the construction of the Shannon Hydro-electric Scheme in the 1920s the level of Lough Derg has been controlled as a reservoir hydraulically linked through Killaloe to Parteen Basin. Control is primarily exercised by releases through Ardnacrusha Power Station, but with additional compensation water releases and spilling of excess flood flows at Parteen Weir.

The ESB Regulations and Guidelines indicate the operating procedures for both flood management and routine operations. Issues covered relate to dam safety, maximum rates of drawdown and compensation releases in addition to the passage of floods.

For flood management the regulations define a Maximum Normal Operating Level of 33.56 mOD, with an Exceptional Reservoir Level of 34.00 mOD. The latter relates

primarily to Parteen Basin and provides a freeboard allowance of 1.0 m for wave action on the earthen embankments upstream of the weir. During all floods the water level at Parteen is reduced to around 32.7 mOD. Therefore, the freeboard allowance of 1m referred to above is always greatly exceeded at the embanked Parteen basin during floods even though the level in Lough Derg upstream is considerably higher.

ESB records show that the Exceptional Reservoir Level in Lough Derg has only been exceeded on two occasions: 34.01 mOD in February 1995 and 34.33 mOD in November 2009, although a lake level of 34.10 mOD was recorded in January 1925, prior to the commissioning of the hydro-electric scheme. In both February 1995 and November 2009 the maximum water level upstream of Parteen Weir was around 32.7 to 32.8 mOD, the head difference from Lough Derg being required to pass the very high flows of some 750 – 850 m³/s through the river channel at Killaloe and the Parteen Basin.

The OPW report (OPW, 2004), a Pre-Feasibility Study on River Shannon Flood Risk Management Opportunities, refers on page 30 to a concern of the IFA that the operation of Lough Derg increases flood levels **upstream** of Meelick Weir. This concern was not raised specifically during the consultation meeting with the IFA on 20 April 2011.

We have studied the explanation provided in the OPW report, particularly the sensitivity analysis carried out using the hydraulic model developed during the study from Lough Ree to Portumna. The analysis was undertaken for both the 1 in 100 “seasonal flood” - i.e. between mid March and mid October (about 450 m³/s peak flow at Banagher) and the winter 1999/2000 flood event (565 m³/s peak flow at Banagher from OPW records). The model was run with the actual Lough Derg level and with levels 0.25 m higher and lower than the actual level. The hydraulic model runs confirm the recorded flood profiles which show that, during significant flood events, there is a relatively steep hydraulic gradient in the 8 km reach between Victoria Lock and Banagher. This feature is also evident for the 2009 flood events as indicated on Figure 1.2.

We are satisfied that, as concluded in the OPW report, this analysis confirms that there are no impacts on flood levels above Meelick Weir from the operation of Lough Derg.

7.8 Summary

Following the literature review, initial data analysis and consultation with the Electricity Supply Board (ESB), Waterways Ireland (WI) and the Irish Farmers Association (IFA), it was concluded that current operation of the principal control structures at Lough Allen (Bellantra Sluices), Parteen Weir and Ardnacrusha Power Station and the navigation weirs upstream of Lough Ree does not have a significant impact on the occurrence, degree or duration of flooding.

The principal area on the River Shannon with the greatest concerns relating to the impact of water level control operations on flood risk is the callows area between Athlone Weir and the water level control structures in the vicinity of Meelick and Victoria Lock. The remainder of this report therefore focuses on this area.

8

Water Level Variations in the Callows**8.1 Introduction**

From the review of current operating procedures in Section 7 it is clear that flooding in the area of the callows between Athlone Weir and Meelick is the key aspect relating to flood risk management which has raised repeated concerns over the last 150 years. This concern was reiterated at the meeting with the IFA on 20 April 2011, with the reach from just south of Athlone down to Banagher, both left and right banks, being identified as the most vulnerable area and which is subject to extreme regular flooding.

The IFA expressed the view that the Athlone Weir gates should be opened to increase the available storage capacity of Lough Ree prior to periods of increased flood risk to save the callows from severe flooding, particularly summer flooding which is the IFA's main point of concern. Generally the IFA accept that farmland within the floodplain is liable to flooding in the winter and have less concern with this; it is repeated summer flooding and any flooding potentially exacerbated by the operation of control structures on the River Shannon that has the greatest impact on the farmers' livelihood.

Our analysis has therefore focussed on summer floods. We have undertaken an analysis of much of the available data, including water levels as recorded since 1932, with a more detailed analysis of recent summer floods presented in Section 9.

This Section analyses the variation in water levels both upstream and downstream of Athlone Weir over the period from 1932 to early May 2011 for which daily level data was provided by ESB. The analysis focuses on the summer period and focuses on the two "trigger" levels for the impact on the callows – i.e. waterlogging if downstream levels rise above 36.12 mOD and flooding if levels rise above 36.42 mOD.

The main objective of this section is to examine the historic data to see whether there is any evidence that the change in the summer Minimum Normal Operating Level of Lough Ree since 1972 (see Section 7.5 – ESB Guideline 2.7.3.4) has had any impact on the seasonal pattern or frequency of waterlogging or flooding in the callows.

8.2 Level Variations at Athlone Weir

Figure 8.1 at the end of this section shows the overall level variations upstream (Upper Level) and downstream (Lower Level) of Athlone Weir over the summer periods (April to mid October) from 1932 up to early May 2011 in terms of the proportion of the time a given level is exceeded.

Various key levels are identified on Figure 8.1. The historic development of these levels can be more readily understood from the original values in imperial units (i.e. feet above Ordnance Datum Poolbeg) as shown in Table 8.1. The imperial values suggest the intended precision of the original data (i.e. perhaps to 0.5 ft rather than 0.01m as suggested by the metric equivalents). Much of the water level data was originally recorded in imperial units to the nearest inch, which explains the "stepped" nature of the level duration plots.

Table 8.1 Key Levels in Lough Ree and at Athlone Weir

Level	mOD	ft OD
Original Minimum Navigation Level as Shannon Act 1839	37.49	123
Fixed Weir Crest Level	37.40	122.7
Minimum Normal Operating Levels in Lough Ree (current)		
01 Apr – 15 Aug	37.49	123
15 Aug – 01 Oct	37.19	122
01 Oct – 31 Mar	36.88	121
Minimum Navigation Level as Electricity (Supply) Act 1927	36.88	121
Downstream level for flooding of callows	36.42	119.5
Downstream level for waterlogging of callows	36.12	118.5

The following observations can be made from Figure 8.1:

- Overall the “trigger” on the downstream (Lower) water level of 36.12 mOD for waterlogging of the callows has been exceeded for 27% of the time during the summer over the period of record. The onset level for flooding of the callows (36.42 mOD) has been exceeded for 18% of the time during the summer.
- The upstream (Upper) water level has exceeded the fixed weir crest level of 37.4 mOD for 77% of the time during the summer.

Figures 8.2 and 8.3 take essentially the same data but provide separate level-duration plots for Early Summer (1 April – 15 Aug) and Late Summer (taken as 16 Aug to 30 Sep for this analysis). The analysis is further separated out into two periods before and after 1972 when the informal change was made to the Minimum Normal Operating Levels.

As noted in Section 4.2.4, early operation of the Ardnacrusha hydro-electric power station relied on careful management of water storage in Loughs Derg, Ree and Allen to optimise storage for power generation. Now with diversification of supply, ESB manages solely on Lough Derg storage and effectively generates power on ‘run of the river’ flows. Active management of storage for power generation would have primarily affected levels in Lough Ree during low flow periods prior to 1972. This effect is included in the historical data (along with the change to Minimum Normal Operating Level, with which it is connected: a lower allowable level in Lough Ree allows for more use of the available storage).

The two periods analysed (i.e. 1932-1971, 1972-2010) both cover almost 40 years. However, the differences in the level duration plots reflect natural variations in river flows between the two periods in addition to the changes in the operating procedures. Therefore, in general, these two causes cannot be distinguished in this analysis.

The following observations on changes to the upstream (Upper) water levels at Athlone Weir can be made from Figure 8.2:

- a) The combination of natural variations in river flows and the change of operating procedures in 1972 have resulted in significant benefits for navigation in terms of raised water levels upstream, particularly over the Early Summer period. The current Minimum Normal Operating Level for this period of 37.49 mOD has been equalled or exceeded for 91% of the time since 1972 compared with only 65% of the time from 1932 to 1971.
- b) For the Late Summer period the current Minimum Normal Operating Level for this period of 37.19 mOD has been equalled or exceeded for 85% of the time since 1972 compared with only 72% of the time from 1932 to 1971.
- c) During the Early Summer period the percentage of the time that the Upper Level has exceeded the fixed weir crest level of 37.4 mOD has increased from 58% (1932-1971) to 64% since 1972.
- d) The corresponding increase during the Late Summer period is from 70% (1932-1971) to 96% since 1971.

Figure 8.3 demonstrates the impact on the downstream (Lower) water levels. As before the impact includes both natural variations in river flows between the two periods in addition to the changes in the operating procedures. Nevertheless, the following observations can be made:

- a) During the Early Summer period the “trigger” level of 36.12 mOD for waterlogging of the callows was exceeded for 23% of the time during 1932-71, increasing to 27% since 1971.
- b) For the Late Summer period the frequency of waterlogging has reduced from 30% to 20%. This suggests that over the Late Summer period the effect of natural variations reducing flows has more than offset the expected increase in frequency of higher flows as a result of the change in operating procedures for the Lough Ree storage.
- c) The corresponding changes for the onset level for flooding of the callows (36.42 mOD) during the Early Summer period is an increase from 19% of the time (1932-71) to 27% since 1972. For the Late Summer period there is again a reduction, from 19% (1932-71) to 16% since 1972.

8.3 Seasonal Pattern of Flooding of the Callows in Summer

The data on which Figures 8.1 to 8.3 are based has been analysed to show the historic seasonal pattern of flooding during the summer months, and how this has varied before and after 1972. The results are shown in Table 8.2 and indicate that, compared with the earlier years 1932-1971, the incidence of flooding since 1972 has increased in April, May and June, increased marginally in July and late August, decreased marginally in early August and more so in September and early October.

8.4 Flooding and Waterlogging of the Callows in Late Summer

Particular concern has been expressed over late summer (i.e. 16 August to 30 September) flooding in the callows which can have a major impact on damage to the crop before it is harvested.

To demonstrate how this pattern has varied since 1932 we have analysed the records of downstream levels at Athlone, using the “trigger” levels of 36.12 mOD for waterlogging and 36.42 mOD for flooding. This analysis is presented in Table 8.3 with further details in Appendix A.

Period	1932 - 1971		1972 - 2011	
	No. of days where level >36.42 mOD	% of period	No. of days where level >36.42 mOD	% of period
April	338	28%	601	50%
May	147	12%	243	20%
June	73	6%	150	13%
July	44	4%	54	4%
Aug 1-15	50	8%	30	5%
Aug 16-31	52	8%	70	11%
Sep 1-15	123	21%	89	15%
Sep 16-30	180	30%	123	21%
Oct 1-15	237	40%	149	25%

Table 8.3 Incidence of Late Summer High Water Levels in the Callows

Notes:	<ol style="list-style-type: none"> 1. Water level analysis based on Lower Sill Level (i.e. downstream level) recorded at Athlone Weir between 16 Aug and 30 Sep. 2. For water levels the “No. of years” represents the number of years in each decade/period in which water levels exceed the “trigger” level for at least one day. 3. “No. of days” represents the total number of days during the decade/period when water levels exceed the “trigger” level. The maximum possible number in one decade is 460. 4. For rainfall the “No. of years” represents the number of years in each decade/period in which rainfall in August and September as recorded at Athlone exceeded the stated percentage of the Long Term Average (LTA) of 171 mm for 1942-2010. 5. Rainfall data for 1987 is missing from the Athlone rainfall time series.
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Table 8.3 demonstrates that the incidence of downstream water levels which result in waterlogging and flooding of the callows has varied between decades, with a low of only two years out of 10 between 1992-2001 and a high of 7 or 8 years out of 10 between 1942-1951.

There is a marked increase in the frequency of occurrence of downstream water levels which result in waterlogging and flooding of the callows between the low decade of 1992-2001 and the most recent period (2002-2010), with both the number of years and the number of days increasing threefold or more. However, the recent period is no worse than 1942-51 and 1952-61. The variations are likely to be primarily a consequence of climatic variability: this is confirmed by the broad correlation apparent from Table 8.3 between the number of years in each period when the two “trigger” levels are exceeded and the number of years when late summer (August/September) rainfall exceeds 100% or 110% of the long term (1942-2010) average rainfall.

The analysis in Appendix A indicates that, out of the total of 921 days over this late summer period in which the downstream level at Athlone has exceeded 36.12 mOD, 463 days (i.e. 50%) have been associated with an upstream water level of less than 37.9 mOD. The discharge over Athlone Weir at 37.9 mOD is about 93 m³/s, compared with a figure of 100-120 m³/s derived in Section 9.3 f) for total gauged inflow to the callows required to “trigger” the onset of waterlogging of the callows (i.e. Athlone lower sill level rises above 36.12 mOD). It can therefore be concluded that downstream inflows, primarily from the Suck, have a significant influence on the onset of flooding in the callows.

8.5 Conclusion

This analysis confirms the perception that late summer flooding in the last decade has been significantly greater than over the previous four decades or so, but that the incidence of late summer flooding in the two decades 1942-1961 was in fact higher than the period since 2002. Correlation with August and September rainfall records shows that this pattern is likely to be a direct consequence of climatic variability. There is no evidence from this analysis that the change in operating procedures which occurred in 1972, and which affects drawing down the storage in Lough Ree, has had a direct impact on the frequency of late summer flooding in the callows.

A more detailed analysis of the recent summer floods over the four years 2007 to 2010 has been undertaken and this is presented in Section 9.

Level Variation at Athlone Weir - Summer (April to mid Oct) 1932-2011

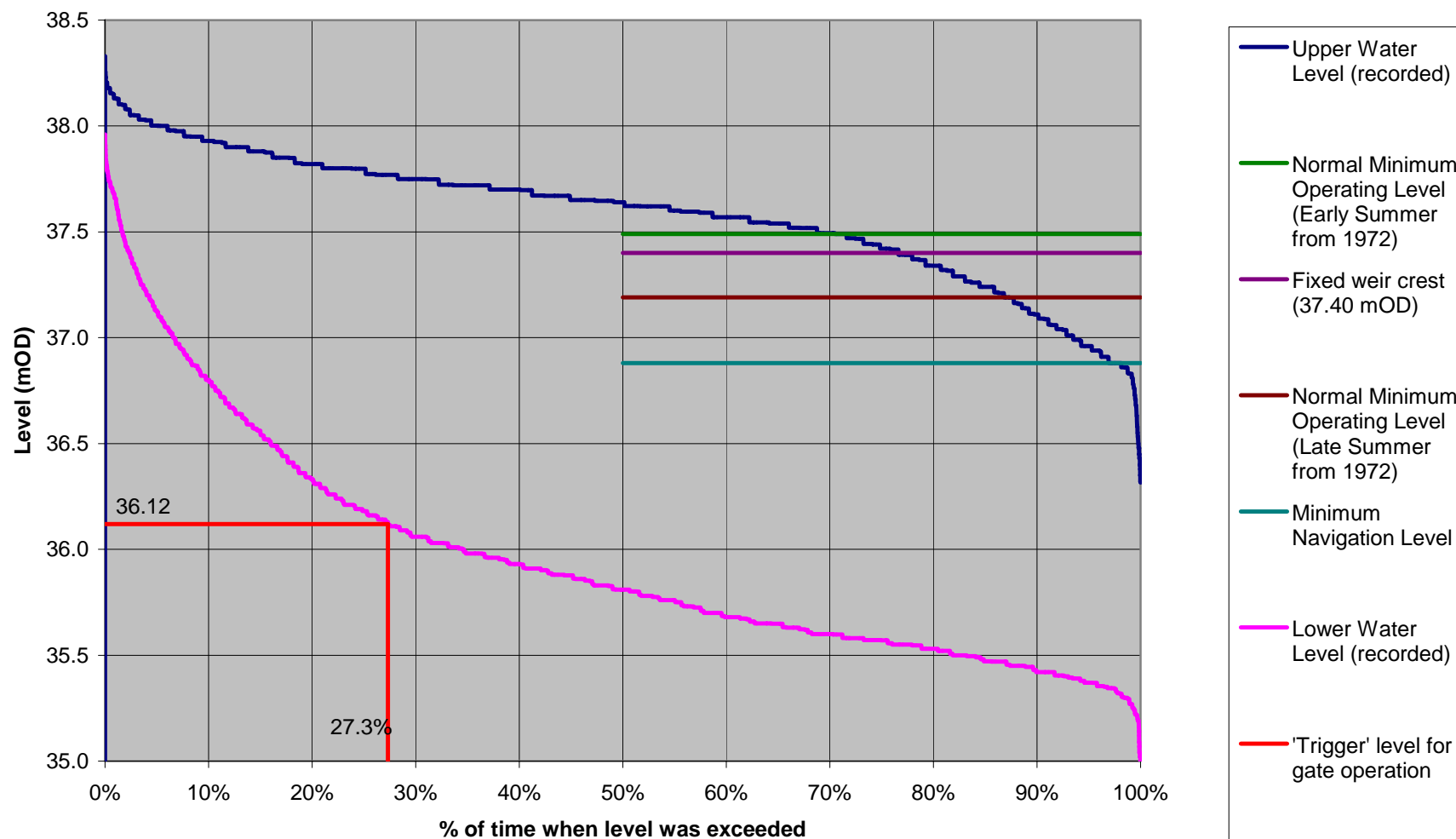


Figure 8.1 Level Variation at Athlone Weir - Summer (April to mid Oct) 1932-2011

Upper Level Variation at Athlone Weir - April to Sep 1932-2011

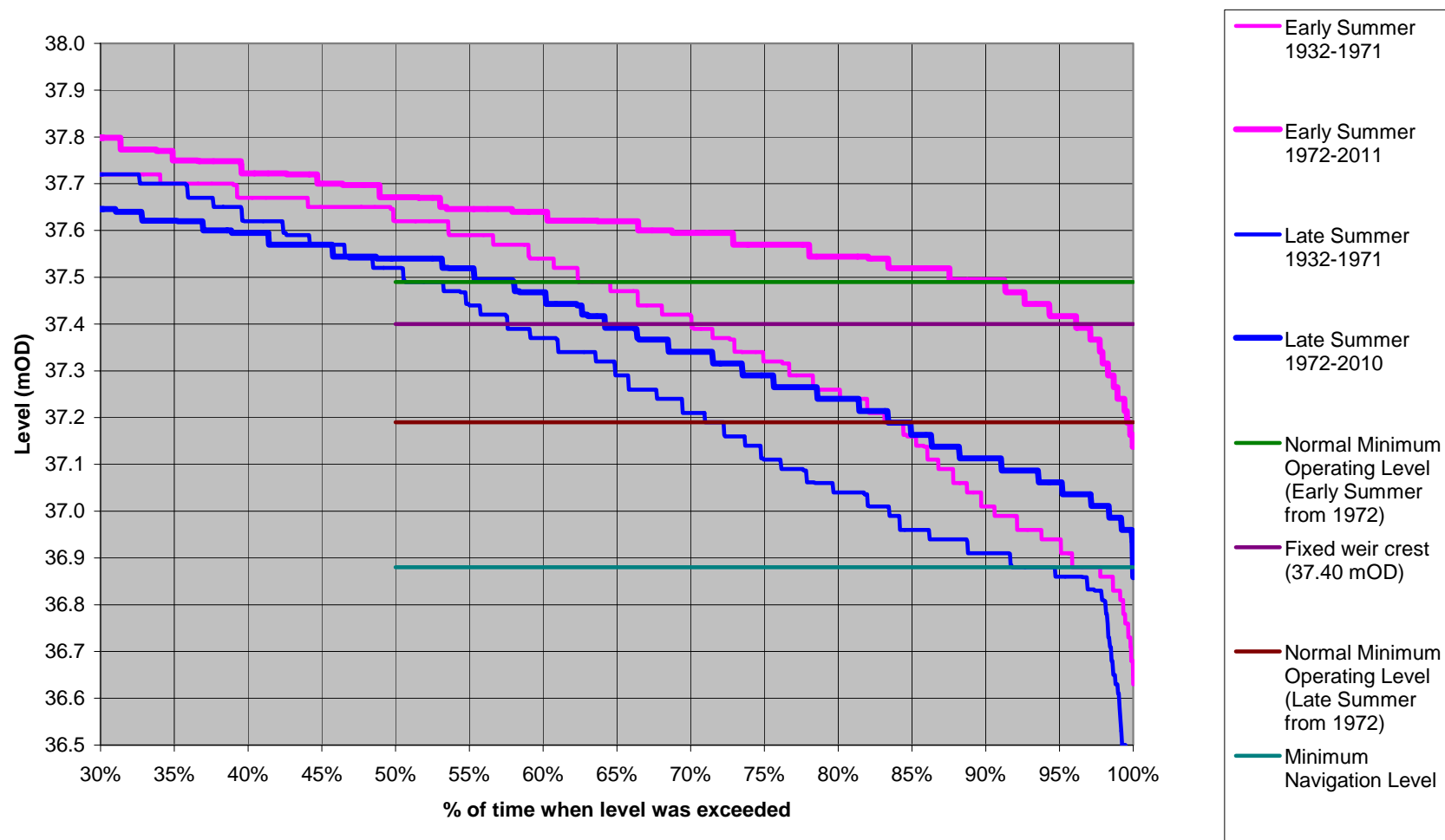


Figure 8.2 Upper Level Variation at Athlone Weir - April to September 1932-2011

Lower Level Variation at Athlone Weir - April to Sep 1932-2011

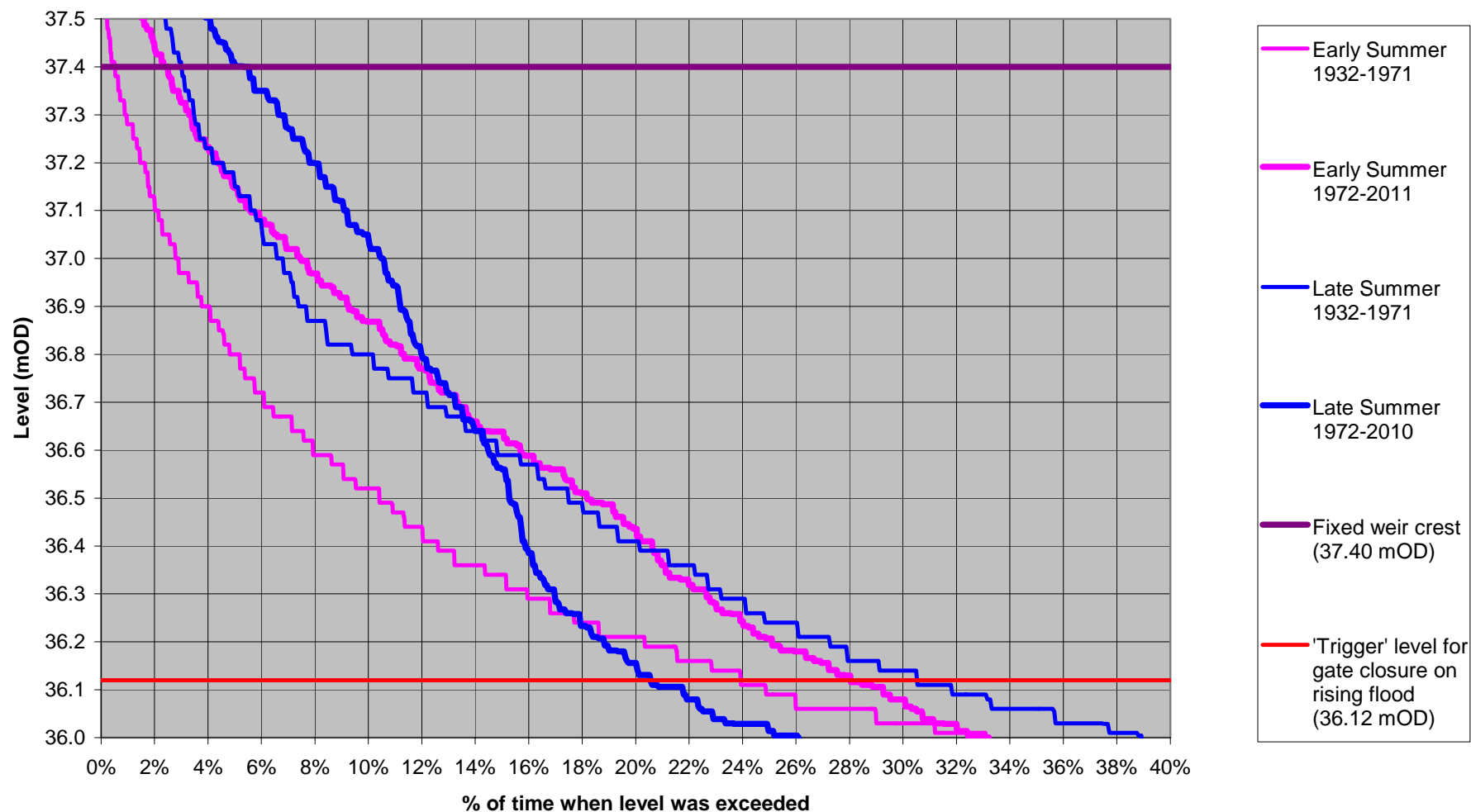


Figure 8.3 Lower Level Variation at Athlone Weir - April to September 1932-2011

9.1 Introduction

The analysis of recorded downstream levels at Athlone in Table 8.3 has shown that there has been a marked increase in summer flooding of the callows over the last decade compared with the previous four decades. We have therefore assembled the available datasets of relevant flows and levels for the four years 2007 to 2010 with a view to:

- improving the understanding of the flood mechanisms which have given rise to the understandable concerns of those adversely affected; and
- assessing the extent to which ESB and WI have operated the relevant water level control structures in accordance with their respective operating procedures and whether such operations have had an adverse impact on flooding in the callows

The callows is predominantly a Special Area of Conservation and a Special Protection Area encompassing the River Shannon floodplain, on both banks, between Athlone and Lough Derg. In addition to the flows from Lough Ree over Athlone Weir, the Shannon flowing through the callows receives significant inflows from the Suck at Shannonbridge and from the Brosna at Shannon Harbour. The whole area over the 37 km reach from Athlone to Banagher is very flat with typical summer water levels at the more upstream points only a few cm above the level at Banagher or at Meelick Weir a further 7 km downstream. Water levels as far upstream as Athlone Weir can be affected by inflows from both the Suck and the Brosna in addition to the Shannon outflow from Lough Ree.

Figure 9.1 shows a simplified diagram of the callows area. Table 9.1 summarises the catchment areas which contribute flow to the callows. From this table it is apparent that the outflow from Lough Ree at Athlone is derived from 57% of the total catchment area at Banagher. Of the remaining area contributing flows to the callows, 30% is gauged (on the Suck at Bellagill and on the Brosna at Moystown), with the remaining 13% being ungauged.

During a rising flood, the water level downstream of Athlone and in the callows can be increased by floodwaters from the Suck (and Brosna), especially when the flood peak precedes that coming through Athlone from the upper Shannon. The high level of the Meelick Weir sill (and boards, if in place) ensures minimal channel gradient from Athlone down to Meelick Weir, so the Suck (and possibly the Brosna) could flow both downstream towards Meelick and backwater upstream to Athlone. This accounts for much of the variability seen in levels and flows exiting Lough Ree. At higher levels, the natural channel hydraulic constraint between Shannonbridge and Meelick Weir becomes the hydraulic control, with a flatter hydraulic gradient between Athlone and Shannonbridge, as can be seen on Figure 1.2. Approximate level-discharge relationships for Lough Ree, Athlone Weir, the callows, Banagher and Meelick Weir are provided in a summary graphical form in Appendix B.

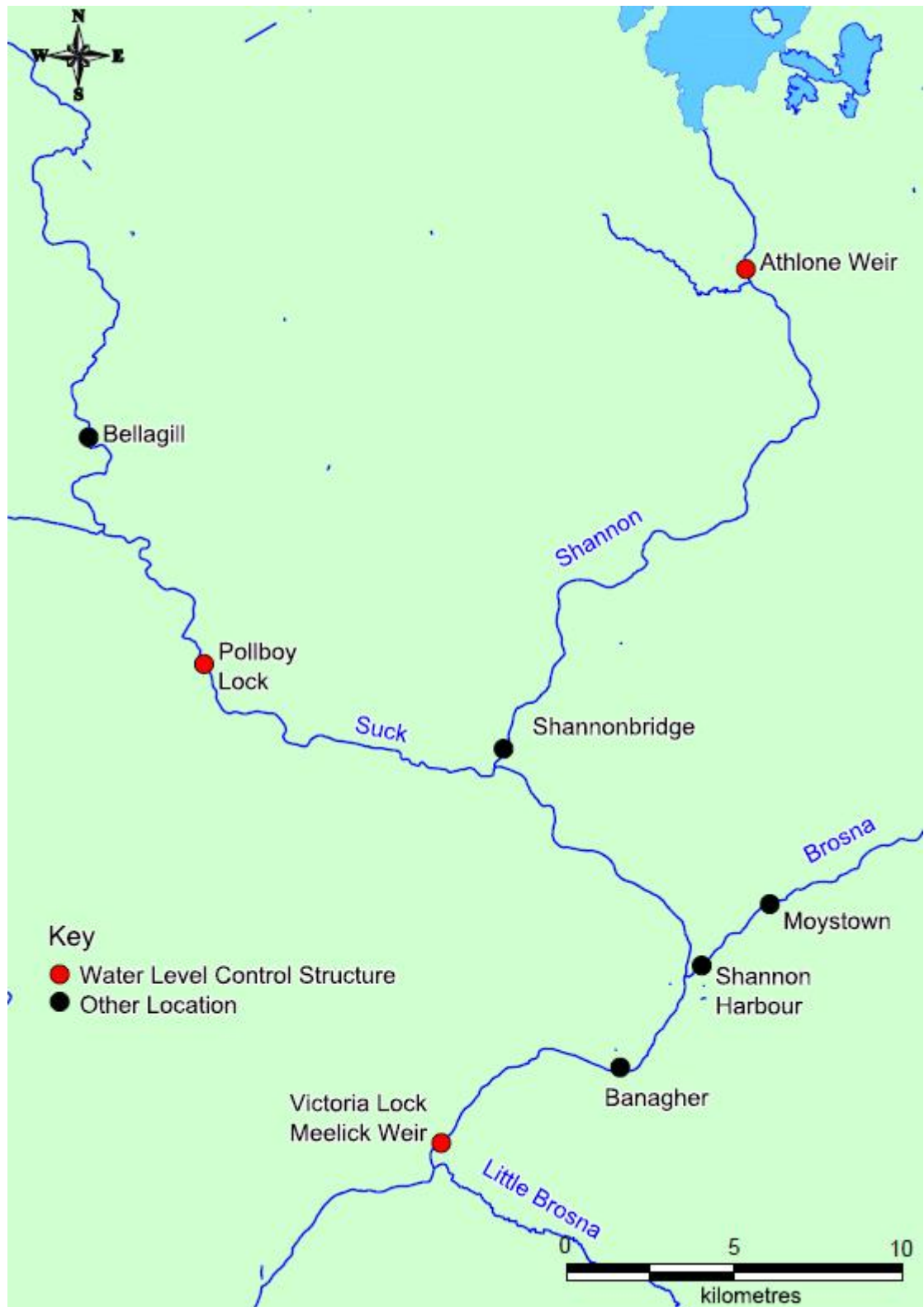


Figure 9.1 Map of the Callows area between Athlone and Meelick Weir

From this high level overview it is clear that flooding in the callows is not only affected by the outflow from Lough Ree, but also by the significant inflows from the Suck and the Brosna. In contrast to the Shannon inflow to the callows, which is attenuated by the effect of Lough Ree, the Suck and the Brosna are not only largely unregulated, but have active maintenance regimes to maximise channel conveyance.

Table 9.1 Catchment Areas Contributing Flow to the Callows

Catchment	OPW Gauging Station Ref	Approx Area (km ²)	% of catchment at Banagher
Shannon at Athlone	26027	4580	57%
Suck at Bellagill	26007	1200	15%
Ungaaged incremental Suck to Shannonbridge		400	5%
Ungaaged incremental Shannon to Shannonbridge		420	5%
Brosna at Moystown	25011	1180	15%
Ungaaged incremental Shannon/Brosna to Banagher		200	3%
Shannon at Banagher	25017	7980	100%

It is beyond the scope of this report to examine possible changes to the hydrological regime of the Suck and the Brosna. It is noted that Lough Ennell in the Brosna catchment moderates flows at higher flows, and is used as a millpond for power generation at lower flows. However, Lough Ennell is towards the upper end of the Brosna catchment and therefore has a relatively small effect on the overall catchment flows as gauged at Moystown. Drainage of the Brosna was completed in 1955; drainage of the Suck was completed in c.1895. Both these arterial drainage schemes are likely to have had the effect of advancing the timing of flood flow runoff relative to the Shannon.

Flow data is available for the Suck and the Brosna covering the summer periods of 2008 and 2009 and this data has been used to provide a more complete picture of the factors influencing flooding in the callows.

9.2 Details of Summer Flood Events 2007 - 2010

The relevant available data on flows and levels covering the summer period (i.e. 1 April to 15 October) for each of the years 2007 to 2010 is presented as a series of level and flow hydrographs in Appendix B. Generally the water levels plotted from these graphs are taken from the Waterways Ireland datasets as these provide the greatest relevant geographical coverage. These have been supplemented with OPW records for Shannonbridge levels and flow data from the gauging stations on the Suck and the Brosna as well as the Banagher gauge on the Shannon which effectively constitutes the outflow from the main area of the callows.

As noted in Section 6.2, for this study we have calculated flows at Athlone (i.e. the outflow from Lough Ree) based on the equations provided in the ESB May 2011 Preliminary Report, the ESB records of upstream (Upper) and downstream (Lower)

water levels and the Waterways Ireland records of gate openings. The ESB discharge equations take account of a total of 21 flood flow measurements. They range from 41 m³/s to 380 m³/s and include 4 flow measurements taken by EPA taken in November 2009.

9.2.1 Summer 2007

At the beginning of April the downstream (Lower Sill) water level at Athlone was above the flooding “trigger” level of 36.42 mOD. Water levels dropped well below the waterlogging “trigger” level of 36.12 mOD by the middle of April and remained fairly steady until early July. A summer flood event through to the end of August kept water levels above 36.12 mOD for over seven weeks and above 36.42 mOD for just over six weeks, with the flood receding below 36.12 mOD from 3 September.

Waterways Ireland records for the Meelick and New Cut sluices show that they were fully open until 8 April and from 12 July to 31 August. These periods coincide with the flood periods noted above.

The records for Athlone Weir show that the sluices were kept closed from the preceding winter until the drier period in the late summer and autumn of 2007. Three sluices were open from 12 September, 4 from 29 September, increasing to 6 from mid October until 30 November, when all sluices were closed. The downstream level rose above 36.42 mOD from 2 December.

Figure 9.2 summarises the hydrometric data for the Summer 2007 flood event, with corresponding data for the whole of the summer period in Appendix B.

9.2.2 Summer 2008

At the beginning of April the Lower Sill water level at Athlone was well above the flooding “trigger” level of 36.42 mOD. Water levels dropped well below the waterlogging “trigger” level of 36.12 mOD by the end of April and remained fairly steady until the beginning of July. A minor summer flood event then raised water levels to peak at 36.11 mOD on 8 July, falling back to around 35.6 mOD for over two weeks in late July and early August. A much larger flood event then raised water levels above 36.12 mOD from 13 August and above 36.42 mOD from 17 August. Levels remained very high right through into the following winter.

Waterways Ireland records show that the sluices at Athlone were kept closed throughout the summer of 2008. The records for the Meelick and New Cut sluices show that they were fully open until 22 April and again from 10 August right through until the end of the year. These periods coincide with the flood periods noted above.

Figure 9.3 summarises the hydrometric data for the Summer 2008 flood event, with corresponding data for the whole of the summer period in Appendix B.

9.2.3 Summer 2009

At the beginning of April the Lower Sill water level at Athlone was below the waterlogging “trigger” level of 36.12 mOD at the beginning of April but rose past this level on 11 April. The flooding “trigger” level of 36.42 mOD was exceeded on 26 April and remained above this level until 3 June, before dropping to 35.6 mOD at the beginning of July. A minor summer flood event then raised water levels to peak just below the 36.42 mOD level at the beginning of August. A much larger flood event then rapidly raised water levels above 36.12 mOD from 20 August and above 36.42 mOD from 21 August. Levels remained high for over 5 weeks, then dropping to a minimum of 35.6 mOD in the middle of October, before rising again to the highest recorded winter peak of just over 39 mOD in late November.

Waterways Ireland records show that the sluices at Athlone were kept closed throughout the summer of 2009. The records for the Meelick and New Cut sluices show that they were fully open from 10 April until 3 June (except for 2 sluices closed at Meelick on 23 April) and then again from 16 July to 8 August and again from 19 August until 28 September. These periods coincide with the flood periods noted above.

Figure 9.4 and Figure 9.5 summarise the hydrometric data for the flood events in Summer 2009, with corresponding data for the whole of the summer period in Appendix B.

9.2.4 Summer 2010

At the beginning of April the Lower Sill water level at Athlone was well above the flooding “trigger” level of 36.42 mOD with a late winter flood peaking at 37.79 mOD on 9/10 April. Levels had remained consistently high since the previous August other than through March 2010. Water levels dropped well below the waterlogging “trigger” level of 36.12 mOD by the end of April and remained fairly steady until early July. A minor summer flood event then raised water levels to peak at 36.01 mOD on 22 July, falling back to around 35.5 mOD for a week or so in late August. A much larger flood event then raised water levels above 36.12 mOD from 9 September and above 36.42 mOD from 11 September. Levels remained above 36.42 mOD until 11 October and dropped below 36.12 mOD on 15 October.

Waterways Ireland records show that the sluices at Athlone were closed throughout the summer of 2010, except between 20 July and 7 September when up to 6 sluices were open. The records for the Meelick and New Cut sluices show that they were fully open until 26 April and from 7 September until 13 October. These periods coincide with the flood periods noted above.

Figure 9.6 summarises the hydrometric data for the Summer 2010 flood event, with corresponding data for the whole of the summer period in Appendix B.

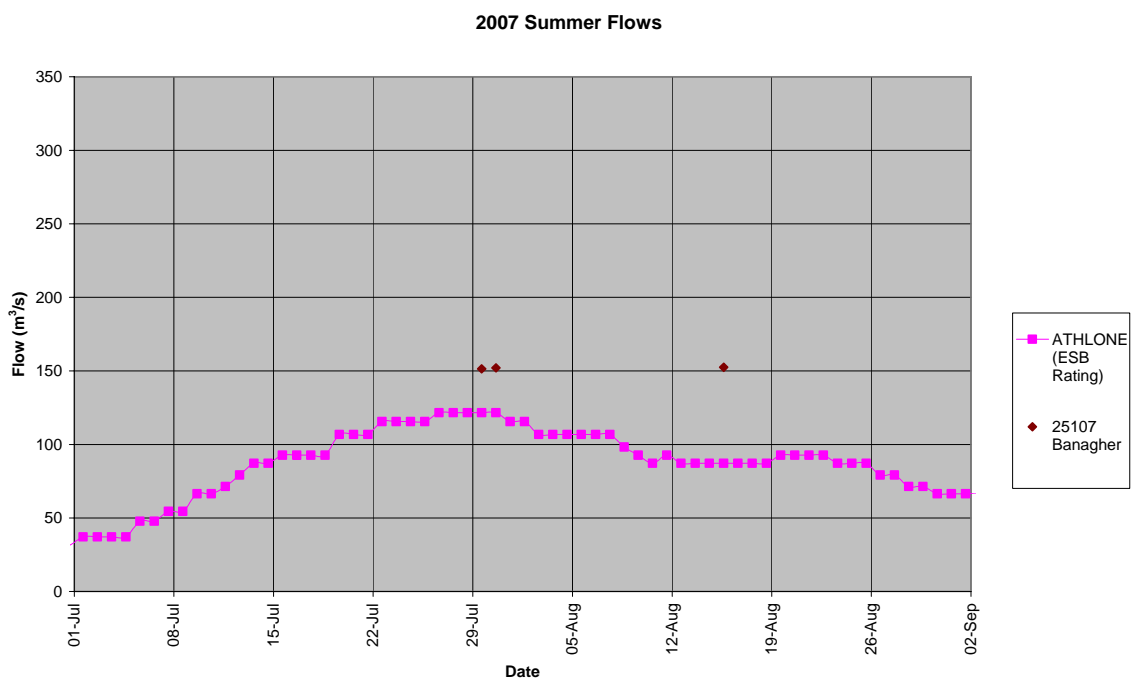
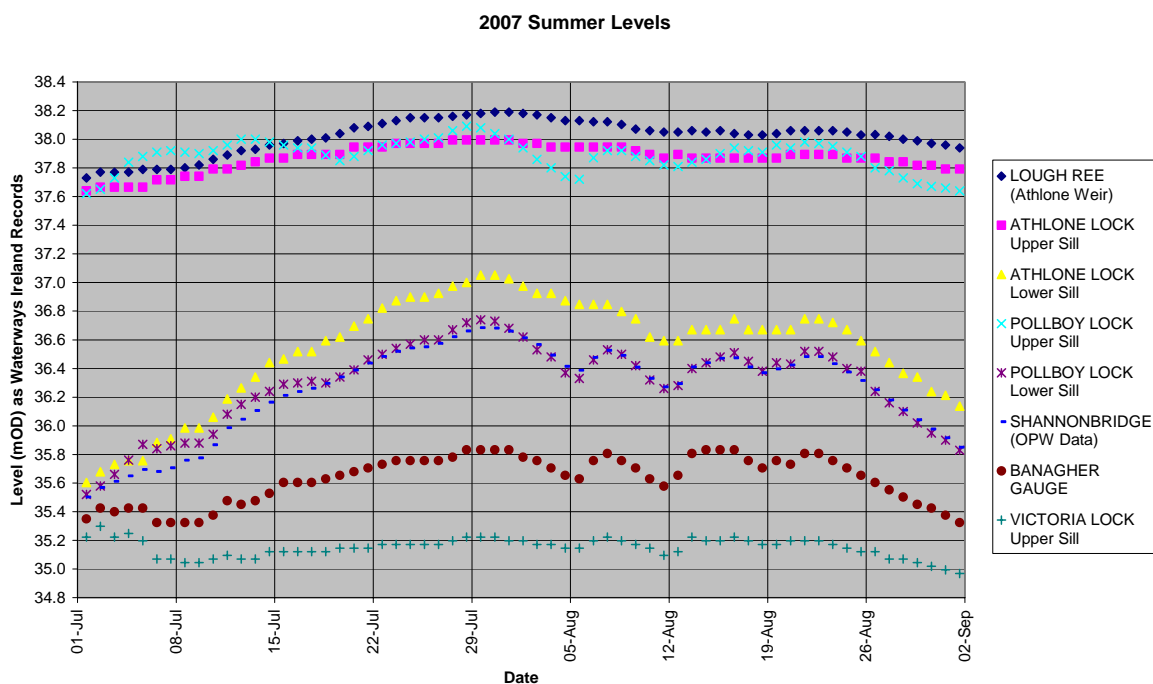


Figure 9.2 Details of Summer Flood 2007 (July- August)

- Notes:
1. Flow data for Suck and Brosna not available for this period
 2. Banagher gauge not rated for flows below 140 m³/s
 3. Meelick and New Cut sluices fully open from 12 July to 31 August
 4. Athlone sluices all closed through Summer 2007 until 12 September

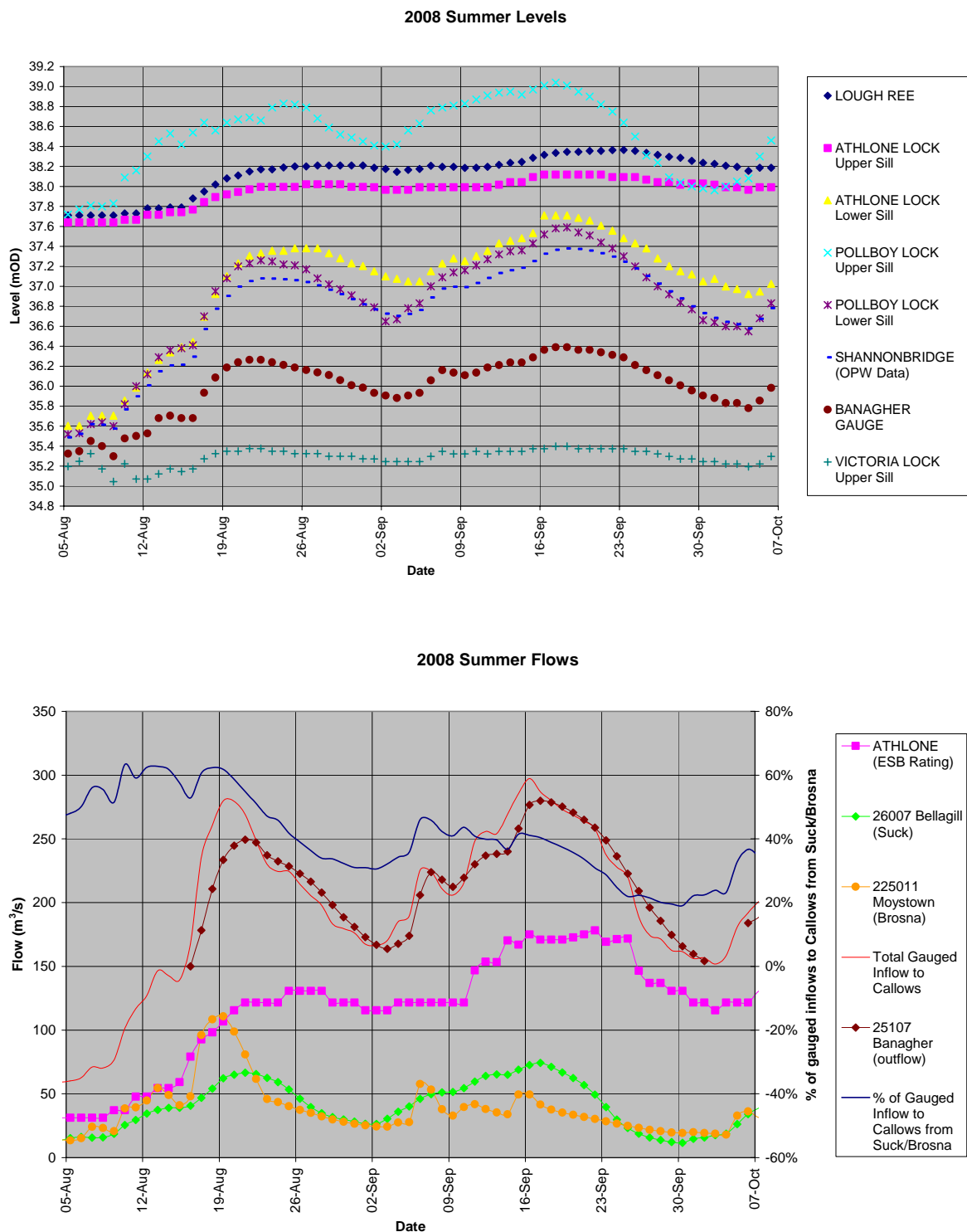


Figure 9.3 Details of Summer Flood 2008 (August-October)

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Meelick and New Cut sluices fully open from 10 August
 3. Athlone sluices all closed throughout Summer 2008

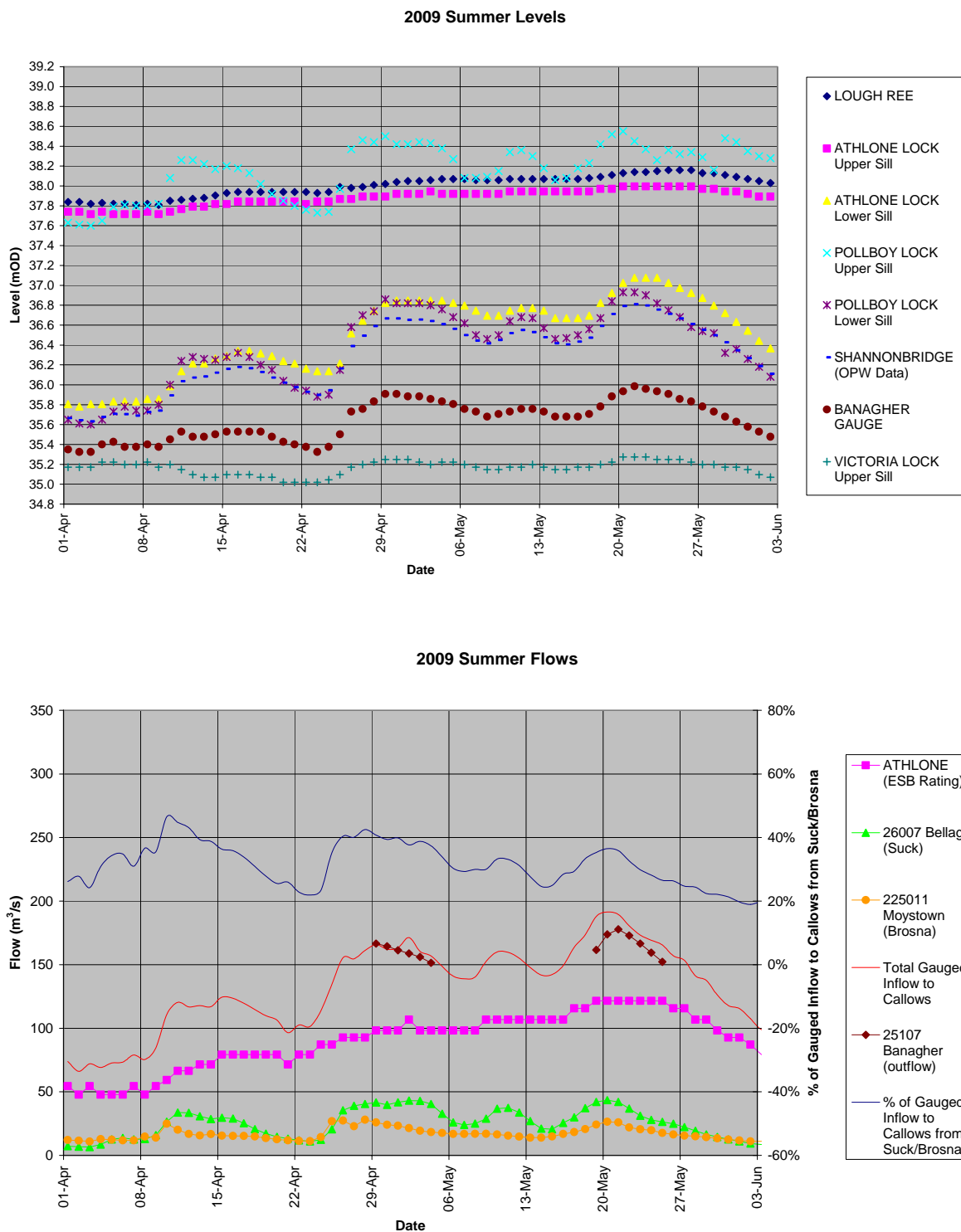


Figure 9.4 Details of Early Summer Flood 2009 (April - June)

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Meelick and New Cut sluices fully open from 10/04 until 03/06 inclusive except for 2 sluices at Meelick closed on 23/04
 3. Athlone sluices all closed throughout Summer 2009

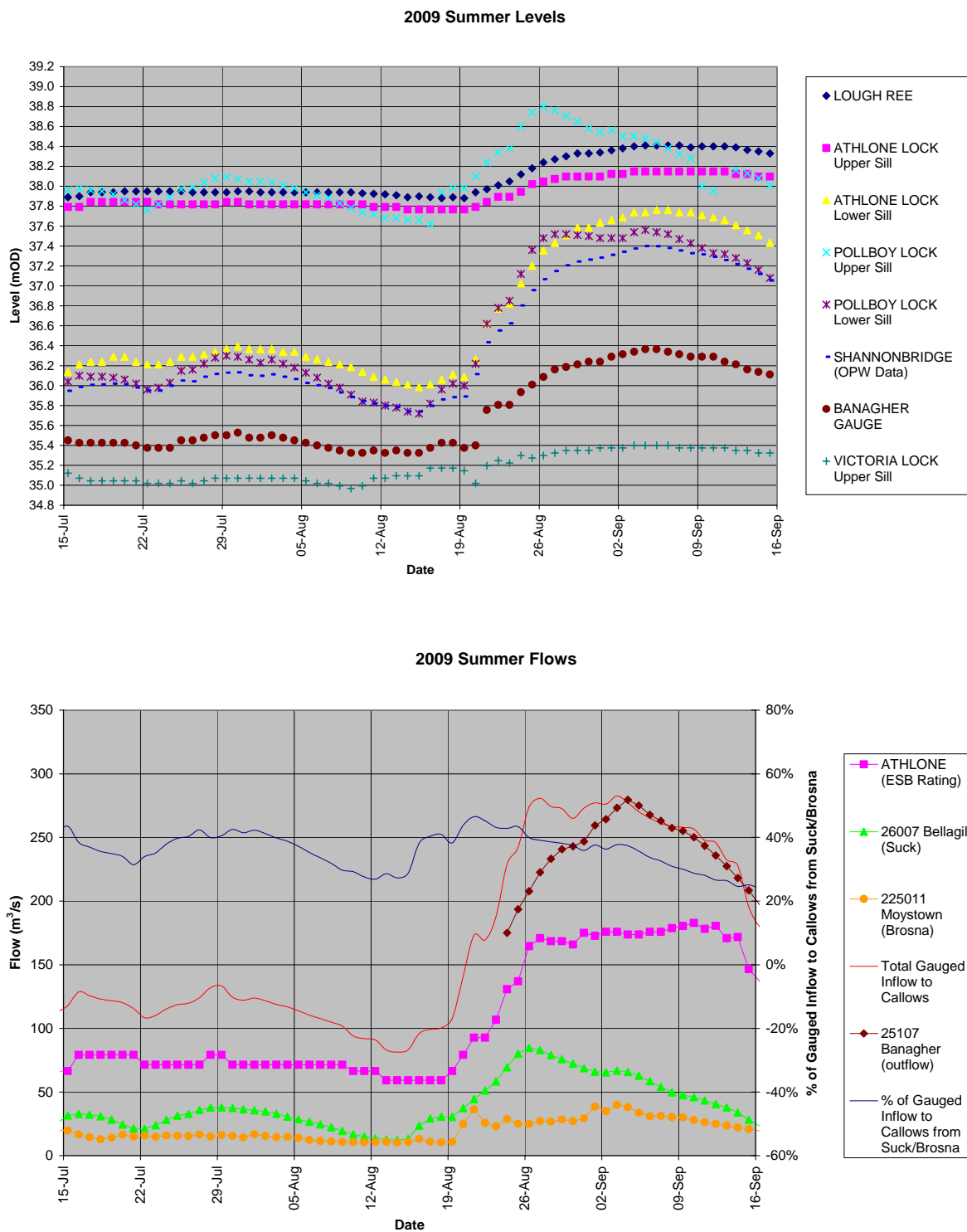
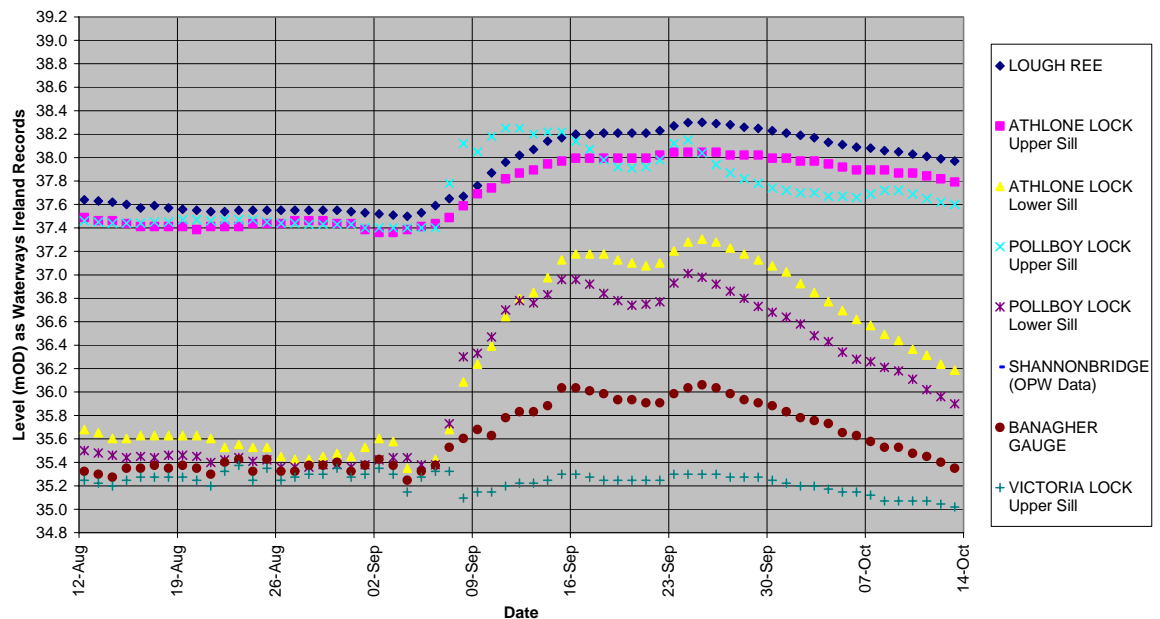


Figure 9.5 Details of Late Summer Flood 2009 (July - September)

- Notes:
1. Banagher gauge not rated for flows below $140 \text{ m}^3/\text{s}$
 2. Meelick and New Cut sluices fully open from 16/07 until 08/08 inclusive and from 19/08 until 28/09 inclusive.
 3. Athlone sluices all closed throughout Summer 2009

2010 Summer Levels



2010 Summer Flows

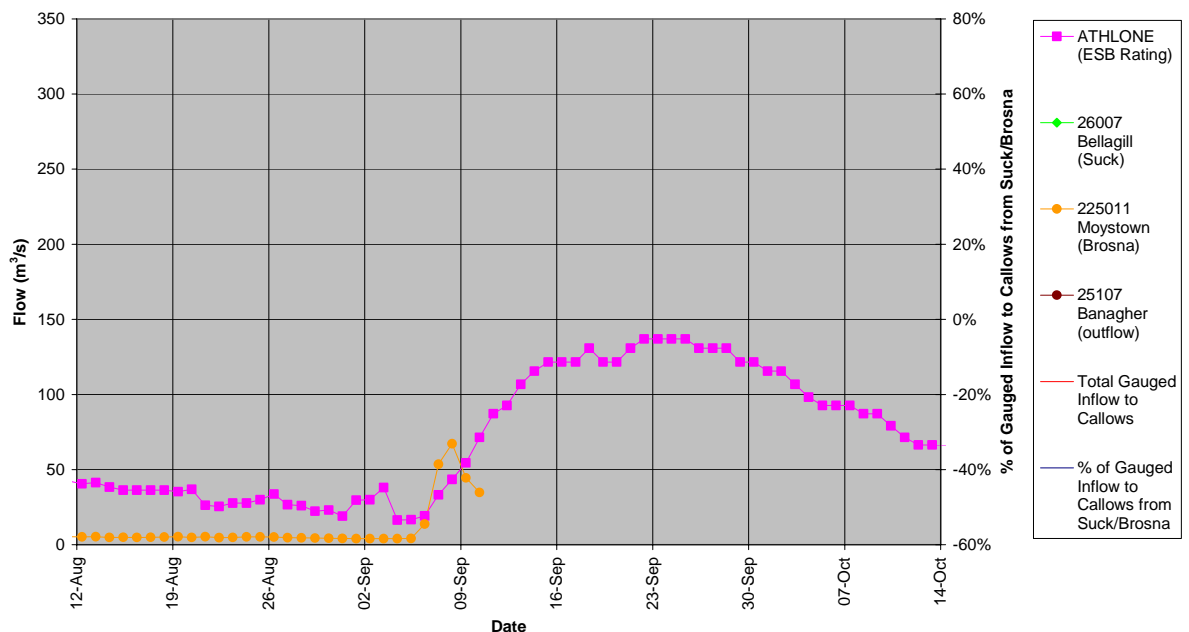


Figure 9.6 Details of Summer Flood 2010 (August - October)

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Meelick and New Cut sluices fully open from 01/04 until 26/04 inclusive and from 07/09 until 13/10 inclusive.
 3. All sluices closed at Athlone except from 20/07 to 07/09 inclusive, with a maximum of 6 open out of the 15 total from 07-20/08
 4. Some OPW data (e.g. Shannonbridge levels, Suck and Brosna flows) not yet available in processed form for the whole of Summer 2010

9.3 General Observations from Summer Flood Hydrographs

The following hydrological and hydraulic features of the callows area are apparent from the summer flow and level hydrographs presented in Appendix B and shown in summary form for the 5 flood events in Figures 9.2 to 9.6:

- a) The level hydrographs for Athlone Lock (lower sill), Pollboy Lock (lower sill) and Shannonbridge all follow each other very closely, which confirms the very flat nature of the callows area and generally minimal hydraulic gradients.
- b) Where available for 2008 and 2009, comparison of the hydrographs for the total gauged inflow to the callows with the outflow represented by the flow at Banagher shows the classic attenuation effect of a significant on-line storage. The flood peak is reduced (even without consideration of inflows from the ungauged part of the catchment) and the time of peak outflow lags the peak inflow by some 2-3 days.
- c) Where the Pollboy Lock (lower sill) and Shannonbridge levels diverge (generally by no more than 0.2m with a maximum of 0.4m in August 2009) the periods coincide with periods of high flows on the Suck. This is confirmed by the Pollboy Lock (upper sill) level which rises substantially in response to flood peaks on the Suck.
- d) The rising limb of floods on the Suck, as characterised by the level hydrograph for Pollboy Lock (upper sill), in all cases reaches a peak several days before the peak level is reached at Athlone Lock (lower sill). This demonstrates that the initial flooding of the callows is driven primarily from downstream inflows backing up to Athlone, rather than the increasing discharges from Lough Ree over Athlone Weir.
- e) The flow hydrographs for the Suck and the Brosna (where available) confirm that during the rising limb of a flood, the proportion of the total gauged inflow to the callows from the Suck and the Brosna rises to over 40%, compared with a typical figure of 20-25% in non-flood periods. In August 2008 this proportion in fact rose above 60%.
- f) From the relationship between Athlone downstream water level and total gauged inflow to the callows for the years 2008 and 2009 (see Appendix B page B-11) it can be concluded that, except for the falling limbs of flood events, waterlogging of the callows (i.e. Athlone lower sill level rises above 36.12 moD) generally occurs when the total gauged inflow to the callows is in the range 100-120 m³/s. Flooding (i.e. Athlone lower sill level rising above 36.42 moD) begins to occur when the total gauged inflow rises through the range 125-140 m³/s.
- g) From the hydrographs for the years 2008, 2009 and 2010 it can be concluded that, as a flood recedes, the critical level at Athlone Lock (lower sill) of 36.12 moD for waterlogging of the callows is generally passed when flows at Athlone drop below 70-80 m³/s, when typically this will constitute between 70 and 80% of the total gauged inflow to the callows (i.e. a total of 90-100 m³/s).

9.4 Review of Sluice Operations at Meelick

For the 5 summer flood events considered, the Waterways Ireland daily summary records of sluice operations at Meelick Weir and at Marlborough on the New Cut confirm that all sluices were fully open throughout each flood event, coinciding almost exactly with periods when the downstream level at Athlone exceeds the 36.12 moD “trigger” level for potential waterlogging of the callows.

More detailed records have been provided by Waterways Ireland for the flood event of September 2010 from which the timeline in Table 9.2 has been compiled. This demonstrates the typical mode of operation as river conditions change from normal summer levels to a flood event.

Table 9.2 Timeline for Sluice Operations during September 2010 Flood

Date and Time	Water Level at 0900 (mOD)			Sluices Open as WI Daily Summary		WI Notes
	Athlone (Lower Sill)	Banagher (target 35.37 mOD +/- 0.05m)	No. of Athlone Sluices Open	Meelick	Marlborough	
30-Aug	35.48	35.40	3 @ 3ft	1	3	
31-Aug	35.45	35.32	3 @ 3ft	1	3	1
01-Sep	35.53	35.38	5 @ 3ft	1	3	
02-Sep	35.60	35.43	5 @ 3ft	1	5	2
03-Sep	35.58	35.38	5 @ 3ft	1	4	3
04-Sep	35.35	35.25	2 @ 3ft	NIL	2	4
05-Sep	35.35	35.32	2 @ 3ft	NIL	2	
06-Sep	35.43	35.38	2 @ 3ft	1	3	5
07-Sep	35.68	35.53	2 @ 3ft	12	18	6
08-Sep	36.09	35.60	NIL	12	18	
09-Sep	36.24	35.68	NIL	12	18	
10-Sep	36.39	35.63	NIL	12	18	

- Notes:
1. WI opened two sluices at Athlone following an instruction from ESB.
 2. WI opened two sluices at Marlborough. Closed one at 1630 when Banagher level had fallen to 2.13m (35.37 mOD).
 3. WI closed 3 sluices at Athlone on instruction received from ESB at 12:00. The ESB stated that, as Lough Ree level was one inch below the level it should be at, they wanted to carry out an experiment. The purpose of the trial was to see how long it took for the closing of Athlone Sluices to have an effect at Banagher.
 4. The effect of the closure of the three sluices at Athlone was that the Banagher level had fallen to 2.01m. This meant that sluices had to be closed at Meelick and Marlborough.
 5. That morning WI opened 1 in Marlborough and 1 in Meelick in anticipation of the runoff that would result from the recorded rainfall. Checked the level again at 1500. The level at Banagher was 2.09m. Opened a further 3 at Marlborough.
 6. The WI work crew were in Meelick and commenced opening sluices by 0900. By 1100 all the sluices were opened at Meelick and at 1200 all the sluices were opened at Marlborough. The crew of the Coill-an-Eo (WI's principal maintenance vessel for the Shannon Navigation) were also removing the weir boards. At 1300 the level at Banagher had fallen to 2.18m (35.42 mOD). WI received an instruction from ESB at 1200 to close all the sluices at Athlone. This was done by 1300. By 1500 all the boards were out and there was nothing further that could be done. The level began rising again after 1300 and continued to rise.

From our study of the records of water levels and sluice operations of 5 recent summer flood events, we have concluded that Waterways Ireland have operated the sluices at Marlborough and Meelick in accordance with the accepted operating procedures. As noted in Section 7.6, we have previously concluded that sluice operations by Waterways Ireland at Meelick and the New Cut (Marlborough) have no adverse impact on flooding in the callows provided the sluices are operated in accordance with the normal procedures.

9.5 Review of Sluice Operations at Athlone

2007, 2008 and 2009 were particularly wet summers. In the absence of any reliable long term forecasting, ESB exercised its discretion under the Guidelines, taking account of water levels, flows, recent rainfall, Met Eireann weather forecasts and ESB's forecasting model, not to open the Athlone Weir sluices for most of 2007 and not at all during 2008 and 2009. This avoided the possibility of exacerbating waterlogging or flooding in the callows downstream. During the drier period in the late summer and autumn of 2007, after the water level had dropped below the downstream "trigger" level of 36.12 mOD for waterlogging of the callows from 3 September, three sluices were opened from 12 September, 4 from 29 September, increasing to 6 from mid October until 30 November. All sluices were then closed as downstream water levels rose above the "trigger" levels.

During the summer of 2010 some sluices were open from 20 July but all had been closed by 1300 on 7 September, well before the downstream "trigger" level of 36.12 mOD for waterlogging of the callows was reached on the morning of the 8 September.

This confirms that the ESB Regulation 1.5.7.2 (which requires all sluices to be closed during the summer period whenever the downstream water level exceeds 36.12 mOD) has been followed during these 5 recent summer flood events.

For routine operations ESB Guideline 2.7.3.2 states, subject to various constraints:

- *Between April and June, if the level in Lough Ree is above 37.80 mOD, then open the sluices at Athlone gradually to lower the lake level to 37.65 mOD.*
- *Between July and mid- August, if the level in Lough Ree is above 37.70 mOD, then open the sluices at Athlone gradually to lower the lake level to 37.55 mOD by the end of August.*

The foregoing optimises storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years.

- *To optimise storage in Lough Ree from mid-August to October, sluices should be operated to reduce the level in Lough Ree to 37.19 mOD by mid-October provided downstream levels permit.*

Study of the level hydrographs for the 5 recent summer flood events indicate that, in general, the sluices at Athlone have been operated largely in accordance with these Guidelines, subject to the various defined constraints. The following commentary is offered to show the extent to which additional releases might have been made through Athlone Weir and what impact such releases might have had on flooding in the callows.

It should be noted that these are theoretical analyses which have been carried out with the benefit of perfect hindsight (i.e. ignoring the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows at the 36.12 mOD trigger level for waterlogging).

Further details of such impacts are provided in Section 10. The graphs in Appendix B show the relevant hydrographs over the whole of the summer period, with flood events shown in more detail on Figures 9.2 to 9.6. The recorded levels of Lough Ree throughout each of the summers of 2007 to 2010 are indicated on Figure 9.7 together with the "trigger" and target levels for drawdown as defined in ESB

Guideline 2.7.3.2. For each of the summers of 2007 to 2010 we have also derived an outflow series and a net inflow series for Lough Ree (i.e. river inflow plus direct rainfall less evaporation/seepage) as indicated on Figure 9.8 by using the approximate calculated daily discharges over Athlone Weir and the daily change in storage.

9.5.1 Summer 2007

The Lough Ree level on 30 June was 37.73 mOD, i.e. 0.08m above the target level of 37.65 mOD. Some of the sluices could have been opened at Athlone Weir between 9 April when the downstream level had dropped below the “trigger” level of 36.12 mOD and up to 28 April when the Lough Ree level dropped below 37.8 mOD. Similarly some of the sluices could have been opened from 1 July but only for 10 days at most as the downstream level rose above 36.12 mOD on 11 July. Such sluice operations could have been undertaken within the Guidelines and could have drawn down the level of Lough Ree to around 37.63 mOD on 10 July – i.e. on the linear trend of a gradual reduction to the end of August target of 37.55 mOD. The recorded level of Lough Ree on 10 July was 37.86 mOD. The 0.23m difference represents a potential flood storage volume of some 24 million m³.

This storage volume represents about 4 days flow at Athlone over the period 10-13 July. Utilisation of this storage volume could have had some impact on the timing of the initial flooding of the callows, possibly delaying the onset of waterlogging by perhaps 2 or 3 days at most after allowing for the higher initial conditions and downstream inflows to the callows (flow data for the Suck and Brosna are not available for this period to undertake a more detailed analysis). However, there would have been minimal impact on both the subsequent maximum extent and duration of the flooding of the callows which extended for over 6 weeks in July and August.

9.5.2 Summer 2008

The Lough Ree level on 30 June was 37.65 mOD, i.e. the same as the target level of 37.65 mOD. There was a minor flood event in early July which would probably have precluded opening of any sluices until around 10 July. From that date sluice openings could have been made up until about 11 August, drawing down Lough Ree to a minimum level of around 37.59 mOD on 8-9 August – i.e. on the linear trend of a gradual reduction to the end of August target of 37.55 mOD. The recorded level of Lough Ree on 8-9 August was 37.71 mOD. The 0.12m difference represents a potential flood storage volume of some 13 million m³.

As in 2007, utilisation of this storage volume could have had some impact on the timing of the initial flooding of the callows. The extent of this possible delay to the onset of waterlogging is shown from the more detailed analysis presented in Section 10 (Figure 10.1) to be of the order of 2 days, with the onset of significant flooding delayed by less than 1 day, other than in the lowest lying areas where it could have been up to 4 days. However, there would have been minimal impact on both the subsequent maximum extent and duration of the flooding of the callows which extended right through into the winter period.

9.5.3 Early Summer 2009

In early April Lough Ree was only marginally above the 37.80 mOD “trigger” level for possible opening of some of the sluices at Athlone before the downstream level rose above the 36.12 mOD “trigger” level for closing them again on 11 April. The level of

Lough Ree on 9 April was 37.81 mOD and it is therefore clear that any permissible sluice openings in early April to make marginal use of additional flood storage would have had minimal impact on the timing of the subsequent waterlogging of the callows over the next two weeks and no impact at all on both the subsequent maximum extent and duration of the flooding of the callows which extended for some five further weeks until the beginning of June.

9.5.4 Late Summer 2009

The level in Lough Ree was 37.76 mOD on 30 June. This was within the recommended operating band defined in the Guidelines i.e. below 37.80 mOD and above 37.65 mOD and was in the context of a wet summer and in the absence of reliable long term forecasting. Some releases through the Athlone Weir sluices could possibly have been made from 4 June drawing down Lough Ree to a minimum level of around 37.64 mOD on 6 July– i.e. on the linear trend of a gradual reduction to the end of August target of 37.55 mOD. The recorded level of Lough Ree on 6 July was 37.79 mOD. The 0.15m difference represents a potential flood storage volume of some 16 million m³.

Utilisation of this storage volume could have had some impact on the timing of the initial waterlogging of the callows in July. The extent of this possible delay to the onset of waterlogging is shown from the more detailed analysis presented in Section 10 (Figure 10.4) to be about 1 week.

Although we have not analysed all the relevant historical records in detail, the rise of the late summer flood event of 2009 appears to be unusual in that, after an initial rise in early July, the levels (and flows) stabilised over an extended period of some 25 days from mid July, and then dropped slightly before rising at a much faster rate from 20 August. As a consequence, for a period of about six weeks, the downstream level at Athlone remained within the range 35.85 to 36.36 mOD, i.e. within 0.6m of the 36.42 mOD “trigger” level for flooding of the callows. In contrast, for all the other summer flood events which we have analysed the downstream level at Athlone typically rises through this 0.6m range over much shorter periods (2007: 5-13 July: 9 days; 2008: 9-15 August: 7 days; 2010: 7-9 September: 3 days).

The slight drop in water levels in August presented another theoretical possibility for opening of some sluices at Athlone. The downstream water level dropped just below the 36.12 mOD “trigger” level on 9 August when the Lough Ree level was 37.94 mOD – i.e. above the recommended band defined in the Guidelines (37.7 mOD to ~37.6 mOD for that date). Some releases through the Athlone Weir sluices might possibly have been made between say 11 and 19 August, although in the absence of reliable forecasts this might have increased the risk of exacerbating waterlogging and/or flooding downstream if the flood event had evolved differently. Such sluice openings could have drawn down Lough Ree to a minimum level of around 37.82 mOD on 18 August with openings limited to maintain the downstream water levels just below the 36.12 mOD “trigger” level for the whole of that period. The recorded level of Lough Ree on 18 August was 37.89 mOD. The 0.07m difference represents a potential flood storage volume of some 7 million m³.

Utilisation of this storage volume could have had some impact on the timing of the onset of flooding in the callows in August. The extent of this possible delay to the onset of flooding is shown from the more detailed analysis presented in Section 10 (Figure 10.4) to be less than 1 day. However, there would have been minimal

impact on both the subsequent maximum extent and duration of the flooding of the callows which extended for some six weeks through to the end of September.

9.5.5 Summer 2010

The level in Lough Ree on 30 June was 37.65 mOD i.e. at the minimum level of the recommended operating band defined in the Guidelines which ranges between 37.80 and 37.65 mOD. It should be noted that rainfall in June 2010 was considerably below average. Releases through the Athlone Weir sluices were made between 20 -22 July and from 27 July until 7 September. These releases controlled the level of Lough Ree to 37.54 mOD on the 31 August, i.e. marginally below the target level of 37.55 mOD. Lough Ree continued to fall to a minimum of 37.50 mOD on 4 September – i.e. fractionally above the fixed weir crest level of 37.49 mOD and just below the linear trend of 37.52 mOD to give a gradual reduction to the mid October target of 37.19 mOD. See note 3 on Table 9.2 for further explanation of operations around this time. The sluices were fully closed at 1500 hrs on 7 September and the downstream level then rose above the 36.12 mOD “trigger” level on 8 September, primarily driven by downstream inflows (i.e. the Suck and the Brosna) as the flow over Athlone Weir was no more than about 50 m³/s at this time.

This summary confirms that throughout the summer of 2010, the operation of the sluices at Athlone Weir was controlled very closely to follow the ESB Guideline 2.7.3.2. Within the existing Guidelines there was no scope for increasing the available flood storage in Lough Ree prior to the rapid rise in inflows to the callows from 7 September. Hence, within the constraints of Guidelines, the timing of the subsequent waterlogging of the callows over the next two days could not have been significantly influenced by alternative modes of operation of the sluices at Athlone. With the continuing rise in inflows there could have been no impact at all on either the subsequent maximum extent or duration of the flooding of the callows which extended for some 4½ weeks until 9 October.

9.5.6 Volumetric analysis of attenuation potential of Lough Ree

An alternative way of considering the potential for the operation of Athlone Weir to modify the attenuation effect of Lough Ree is to examine the storage volumes which might be potentially available.

Figure 9.8 shows the inflow and outflow hydrographs for Lough Ree for the summers of 2007 to 2010. The substantial “natural” effect of the lake is apparent from this figure, with significant “spikes” in net inflows attenuated resulting in a substantial reduction in the peak outflows. The outflow hydrograph is therefore “smoothed” and substantially greater storage volumes would be required to achieve further attenuation or regulation. For comparative purposes each grid rectangle represents a total volume of 12 million m³, equivalent to a depth of 0.11m over the 106 km² area of the lake. As can be seen, this volume is small compared to the volumes necessary to have a significant impact on the outflow hydrograph which is one of the drivers for the onset and duration of flooding in the callows downstream.

Furthermore, as has been shown in Section 7.5, to avoid exceeding a downstream level of 36.12 mOD (the summer period waterlogging constraint), discretionary control of the level of Lough Ree by opening of the sluices at Athlone can generally only be achieved when the outflow from Lough Ree drops below about 70-80 m³/s, corresponding to a level of about 37.9 mOD. Above this level therefore Lough Ree effectively acts as an unregulated lake. Below this level the scope for regulation is

severely constrained by both the naturally high lake levels in relatively wet summers and the ESB guidelines for limiting drawdown to ensure adequate water levels towards the end of dry summers.

The scope for effective regulation is further constrained when it is appreciated that it is the total inflow to the callows which impacts on flooding there and not just the outflow from Lough Ree. As noted in Section 9.3, during the rising limb of a flood inflows from the Suck and the Brosna can contribute 40-60% of the total inflows. Figure 9.9 shows the corresponding hydrographs for the total gauged inflow to the callows. The critical range in this case above which sluice openings would be precluded is 100 – 120 m³/s on the rising limb and 90 – 100 m³/s on the falling limb. The volume of 12 million m³ represented by a single grid rectangle on Figure 9.9 (equivalent to a depth of 0.11m in Lough Ree) is seen to be even smaller when compared to the volumes necessary to have a significant impact on the callows inflow hydrographs.

Figures 9.8 and 9.9 also help to explain why the Lough Ree starting level has no impact on flood extents during the peak of the event. The increased storage due to possible lower levels identified in Section 9.5 (July 2007: 24 million m³; August 2008: 13 million m³; July 2009: 16 million m³; August 2009: 7 million m³) is represented by between 2 and 0.5 grid rectangles which is very small in comparison to the volume of the hydrograph leading up to the subsequent flood peak. Moreover, with if the level of Lough Ree were to be drawn down further, subsequent outflows on the rising flood would be reduced due to the fixed hydraulic characteristics of Athlone Weir. Hence more of the volume of the rising flood would be retained in Lough Ree, thus effectively “losing” the increased storage before the peak of the event is reached.

9.5.7 Summary

Table 9.3 summarises the impact of potential additional sluice openings at Athlone Weir prior to the recent summer flood events which we have analysed. For some of these summer flood events we have identified some potential delay in the onset of flooding of the callows if the sluices at Athlone Weir had been opened prior to these events. Such sluice openings could have been made within the current ESB Guidelines for the operation of Athlone Weir. However, in no case would there have been anything other than a minimal impact on either the subsequent maximum extent or duration of the flooding of the callows.

It should be borne in mind that three of the four summers that were analysed were considerably wetter than average. In the absence of any reliable long term forecasting ESB exercised its discretion under the Guidelines not to open the Athlone Weir sluices during these wet summers and possibly exacerbate flooding in the callows downstream. In contrast, the above analyses and possible improvements to outcomes are based on perfect hindsight.

Table 9.3 Impact of Potential Additional Sluice Openings at Athlone Weir

Flood Event (date taken as start of event)	Level of Lough Ree at Start of Event				Potential Delay to onset of Flooding if Target Water Level had been Achieved ³
	Recorded Water Level (mOD)	Level ¹ to initiate drawdown (mOD)	Target Water Level ² (mOD)	Difference (m)	
10 Jul 2007	37.86	37.70	37.63	0.23	see note 4
8-9 Aug 2008	37.71	37.70	37.59	0.12	< 1 day (note 5)
9 April 2009	37.81	-	-	-	none
6 Jul 2009	37.79	37.70	37.64	0.15	36.42 mOD level not reached until August
18 Aug 2009	37.89	37.70	37.82 ⁶	0.07	< 1 day (note 7)
4 Sep 2010	37.50	n/a	37.52	-0.02	none

- Notes: 1. Guideline 2.7.3.2 suggests drawdown can be initiated if Lough Ree level exceeds stated level, provided downstream levels permit
2. Target water level as linear trend with date between levels quoted in ESB Guideline 2.7.3.2
3. Onset of flooding taken as 36.42 mOD d/s level
4. Cannot be reliably determined in the absence of flow data for the Suck and Brosna
5. Potential delay up to 4 days for flooding of the lowest lying areas
6. Potential drawdown constrained by downstream levels and limitation on sluice openings in ESB Regulation 1.5.3.2.
7. Potential delay up to 36 hours for a small level range at about 36.75 mOD
8. Potential delay based on perfect hindsight and ignores the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows.

Lough Ree Summer Levels 2007 - 2010

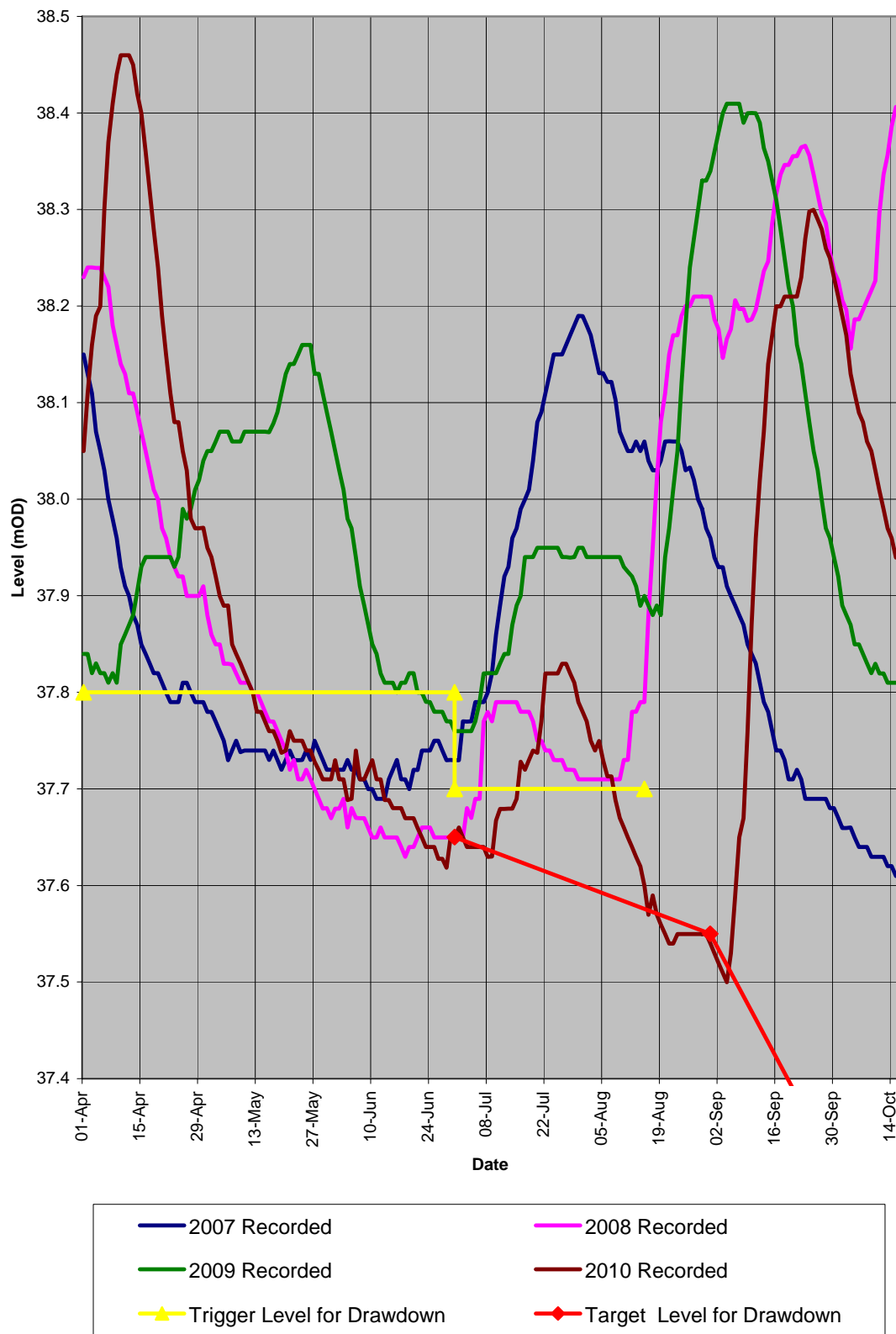


Figure 9.7 Lough Ree Summer Levels 2007 – 2010

Notes: 1. 'Trigger' and target levels for drawdown as ESB Guideline 2.7.3.2

Lough Ree Summer Flows 2007 - 2010

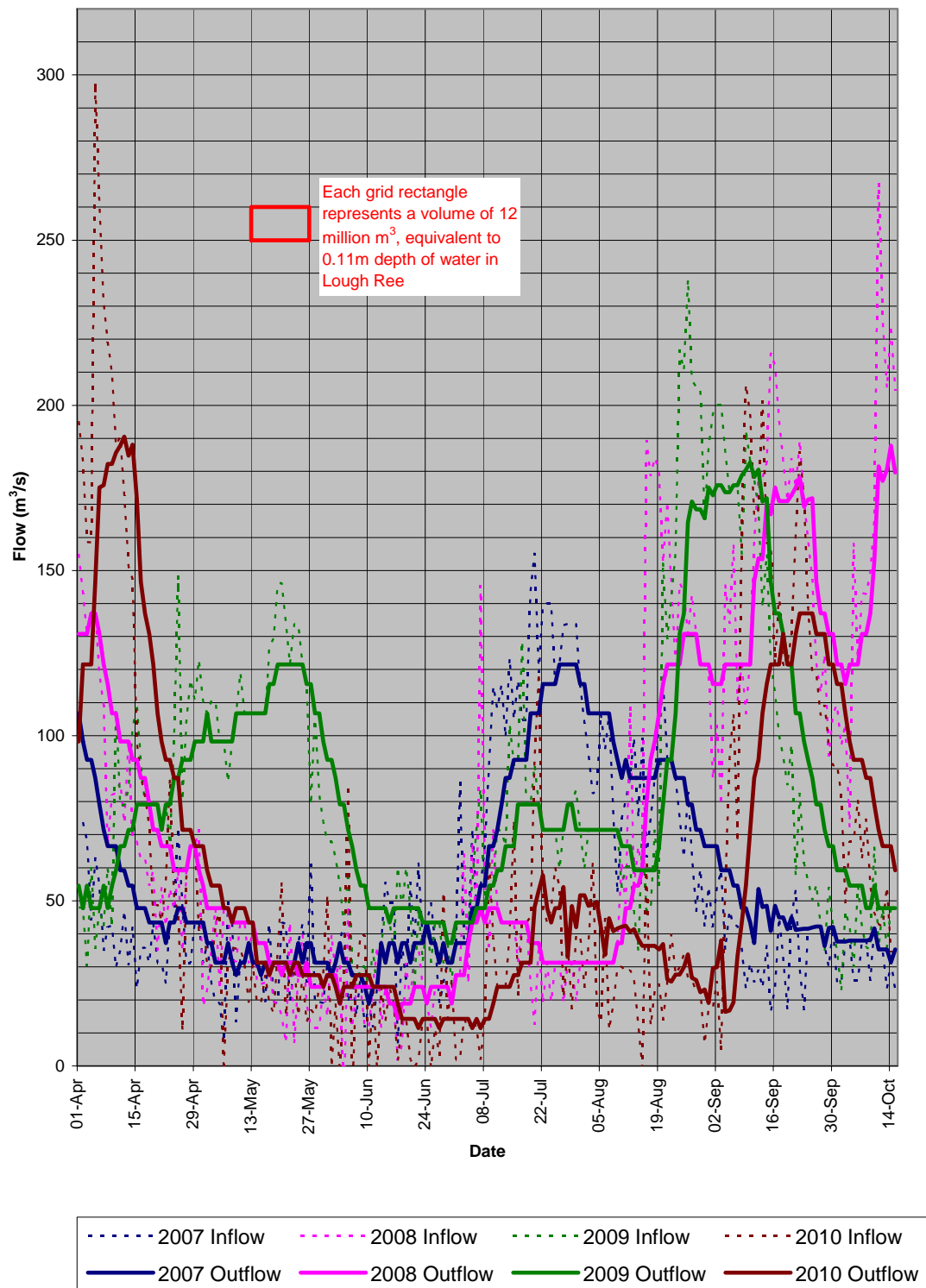


Figure 9.8 Lough Ree Summer Flows 2007 – 2010

Guaged inflows to callows in Summer 2008 - 2010

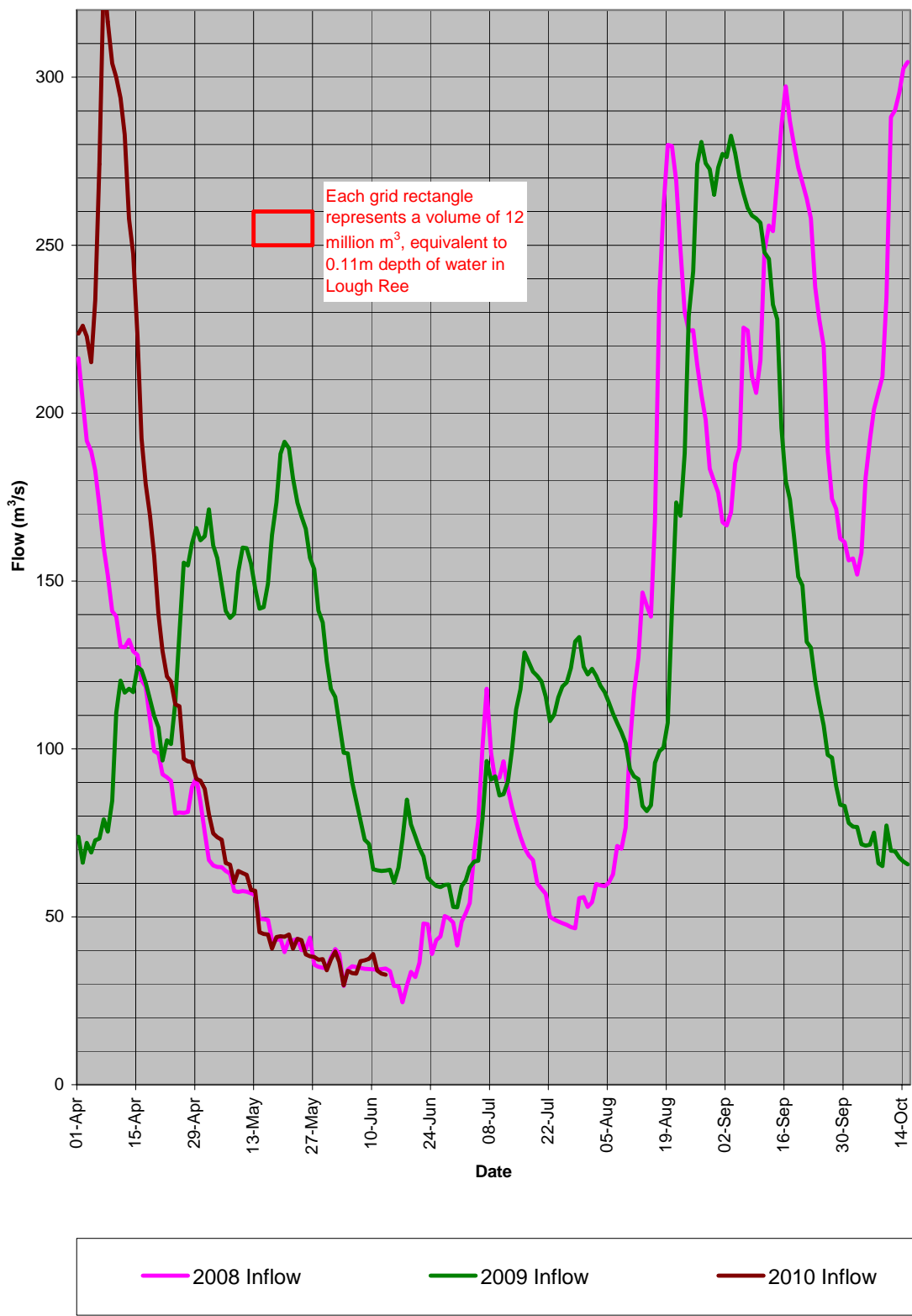


Figure 9.9 Gauged Inflows to Callows in Summer 2008 – 2010

10.1 Methodology

A full analysis of the impact of potential changes to operating procedures at Athlone Weir would require the use of a hydraulic model of the callows area and the use of sub-daily flow and level data from the various gauging stations where this is available or can be derived. It would also be necessary to test a whole range of summer flow patterns to give a representative picture over the 80 or so years of recorded data.

The current operating procedures (ESB Guideline 2.7.3.2) for the April to mid-August period are stated to have the intention of “*optimising storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years*”. Before any changes to operating procedures could be recommended, it would be necessary to demonstrate that any proposed change would provide an overall national benefit in terms of the delicate balance between these two mutually-opposed objectives.

The practicalities of revised operating procedures are also linked to the extent to which significant flood events can be forecast in advance. Technical advances in medium range weather forecasting indicate that forecasts up to 5-10 days in advance are likely to become increasingly reliable. It has been suggested that such forecasts could be used in future to permit additional drawdown of Lough Ree in advance of a flood event with a relatively low risk of the flood not materialising as expected and thereby causing lower than expected levels for navigation. However, to realise the full theoretical flood risk management benefits, drawdown of Lough Ree would be required over an extended period of a month or more – i.e. a longer period than that for which reliable weather forecasts are likely to be available for the foreseeable future.

Detailed analyses of these issues is beyond the scope of this report. However, in order to provide some indication of the extent of potential theoretical benefits in terms of delayed flooding of the callows, we have undertaken a simplified hydrological analysis utilising a daily mass balance model to demonstrate the maximum theoretically-possible impact that revised operating procedures for the Lough Ree storage might have on summer flooding in the callows.

The approach we have used is to analyse the 3 recent summer events for which full daily flow data is currently available (i.e. summer 2008 and early and late summer 2009). We have determined the possible modification to the shape of the total gauged inflow hydrograph to the callows, which will directly influence the pattern of waterlogging and flooding. To do this we have:

- assumed perfect hindsight with respect to the subsequent flood event i.e. forecasting is sufficiently reliable far enough in advance of the event to allow drawdown to the minimum levels assumed for three different scenarios;
- modelled the drawdown of Lough Ree to various pre-determined minimum target levels for navigation immediately prior to the flood event;
- compared the modelled total gauged inflow hydrograph to the callows with that recorded during the event;
- assumed that sluice operation at Athlone Weir, at times where necessary, can be arranged to provide effectively a steady-state total inflow to the

callows, subject to the maximum discharge constraint as a function of upstream level with all 15 sluices open.

The various pre-determined minimum target levels for navigation we have adopted immediately prior to each flood event are, in increasing order of potential benefit in terms of flood risk management in the callows, as follows:

- Scenario (i): A linear trend level based on the target levels at end June (37.65 mOD), end August (37.55 mOD) and mid October (37.19 mOD) specified in the ESB Guideline 2.7.3.2. This is essentially the analysis reported in Section 9.5.
- Scenario (ii): 37.49 mOD until mid August and 37.19 mOD until 1 October (i.e. current minimum normal operating levels as ESB Guideline 2.7.3.4).
- Scenario (iii): As close to 36.88 mOD (i.e. the current statutory Minimum Navigation Level) as is practicable, taking account of the limited sluice capacity at Athlone Weir and the limitations on additional releases when inflows downstream are relatively high and the callows are at risk of flooding.

For Scenario (i), the total steady-state total gauged inflow to the callows has been limited to 100 m³/s – i.e. at the lower end of the range identified in Section 9.3 (f) as desirable to keep the downstream water level at Athlone below the “trigger” level for waterlogging of 36.12 mOD. For Scenarios (ii) and (iii), the steady-state gauged inflow to the callows has been limited to the slightly higher figure of 110 m³/s, which would result in downstream water levels at Athlone being maintained around 36.2 mOD, but still well below the more important “trigger” level for flooding of 36.42 mOD. It is reasonable to assume that such a relaxation could be achieved without adverse impacts with improved flow monitoring and flood forecasting which are inherent in the assumptions behind Scenarios (ii) and (iii),

Scenario (iii) is an extreme and essentially unrealistic scenario to demonstrate the maximum possible flood risk management benefits of alternative operating procedures. If implemented, and in the absence of reliable weather forecasts for around one month ahead, it would be likely to result in severe water level deficits for navigation in years when late summer floods did not materialise.

In addition, the simplified methodology adopted does not take into account the changes in hydraulic losses between Lough Ree and Athlone Weir. With the extreme low target level Scenario (iii) there would be a substantial lowering of lake levels in the weeks before the flood event. Combined with the increased flows compared with those recorded this would significantly reduce the head across the Athlone Weir and hence the available discharge capacity through the sluices when all 15 are fully open. In the absence of a comprehensive hydraulic model we have adopted a simple approximation for the revised downstream water level and assumed that, in Scenario (iii), at the lowest drawdown level the headloss between Lough Ree and Athlone Weir would double compared to that actually recorded.

Tables 10.1 and 10.2 indicate that having all 15 sluices open only applies under the extreme Scenario (iii). Under Scenario (ii) for 2009, although the maximum number of open sluices is shown as 14, this only applies over 4 days of the 2 months or so of potential draw down. Under Scenario (iii) our analysis indicates that all 15 sluices would need to have been open for the majority of the drawdown period.

10.2 Impact of Alternative Operating Procedures in Summer 2008

A preliminary assessment of the impact that the three operating procedure scenarios outlined in Section 10.1 may have on levels and flows in the summer of 2008 is shown on Figures 10.1, 10.2 and 10.3.

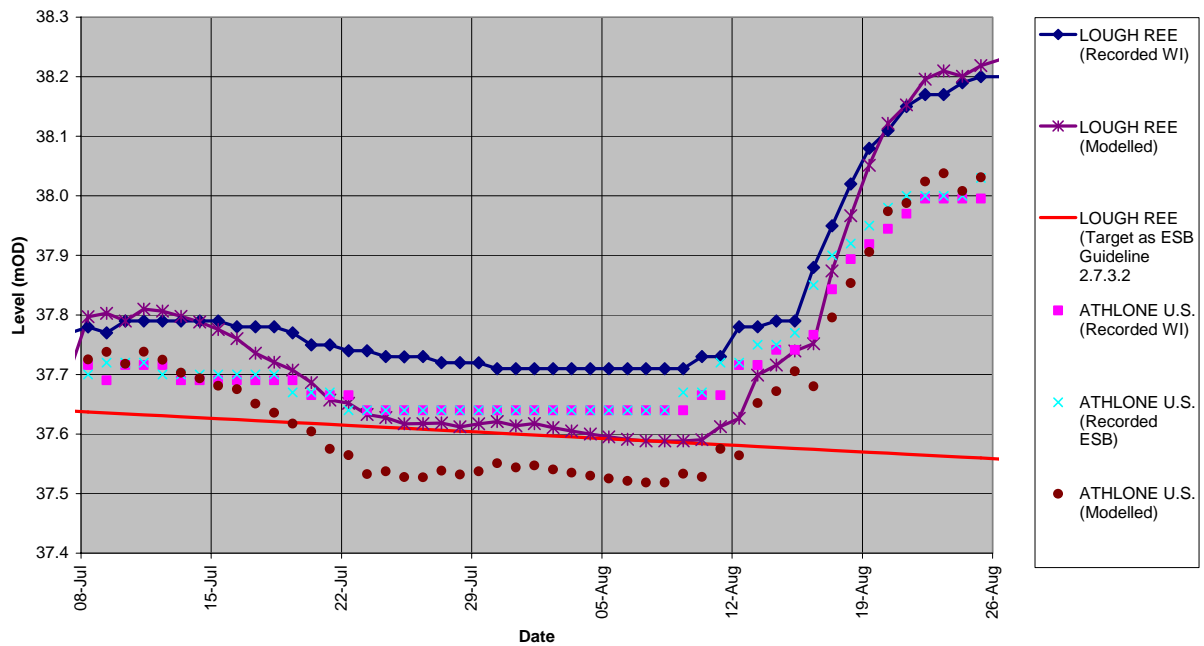
In all cases sluice openings commence on 12 July, generally in increments of 1 sluice per day. More rapid opening of the sluices is likely to exacerbate waterlogging problems in the callows on the recession of the minor flood which occurred that year in early July. Table 10.1 summarises the potential impact on flooding of the callows for the three operating procedure scenarios.

Table 10.1 Potential Impact on Flooding of the Callows of Alternative Operating Procedures in 2008

Mode of Operation – drawdown level of Lough Ree before flood event	Max no. of sluices open	No. of days with stated no. of sluices open		Potential delay to onset of flooding	Notes
		> 0	> 10		
Scenario (i) 37.59 mOD – as ESB Guideline 2.7.3.2	5	32	0	< 1 day (note 5)	1,2
Scenario (ii) 37.49 mOD – as ESB Guideline 2.7.3.4	6	32	0	~1 day (note 5)	2,3
Scenario (iii) Towards 36.88 mOD – i.e. statutory Minimum Navigation Level	15	36	20	~2 days (note 5)	3,4

- Notes: 1. Recorded hydrographs show gauged inflows to callows steady at 140-150 m³/s on 13-15 August. Drawdown of Lough Ree could have reduced this flow to ~125 m³/s.
2. Minimal impact on flood peak on 24-26 August. No impact on subsequent higher flood peak on 16 September.
3. Recorded hydrographs show gauged inflows to callows steady at 140-150 m³/s on 13-15 August. Drawdown of Lough Ree could have reduced this flow to ~110 m³/s.
4. Lowest drawdown level of Lough Ree achieved is 37.05 mOD due to discharge and downstream level constraints. Flood inflow peak on 20 August reduced from 280 m³/s to 200 m³/s but not sufficient to prevent extensive flooding of the callows. No impact on subsequent higher flood peak on 16 September.
5. Potential delay up to 4 days for flooding of the lowest lying areas
6. Potential delay based on perfect hindsight and ignores the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows.

Possible 2008 Summer Levels with Lough Ree drawn down to 37.59 mOD on 8-9 August



Possible 2008 Summer Flows with Lough Ree drawn down to 37.59 mOD on 8-9 August

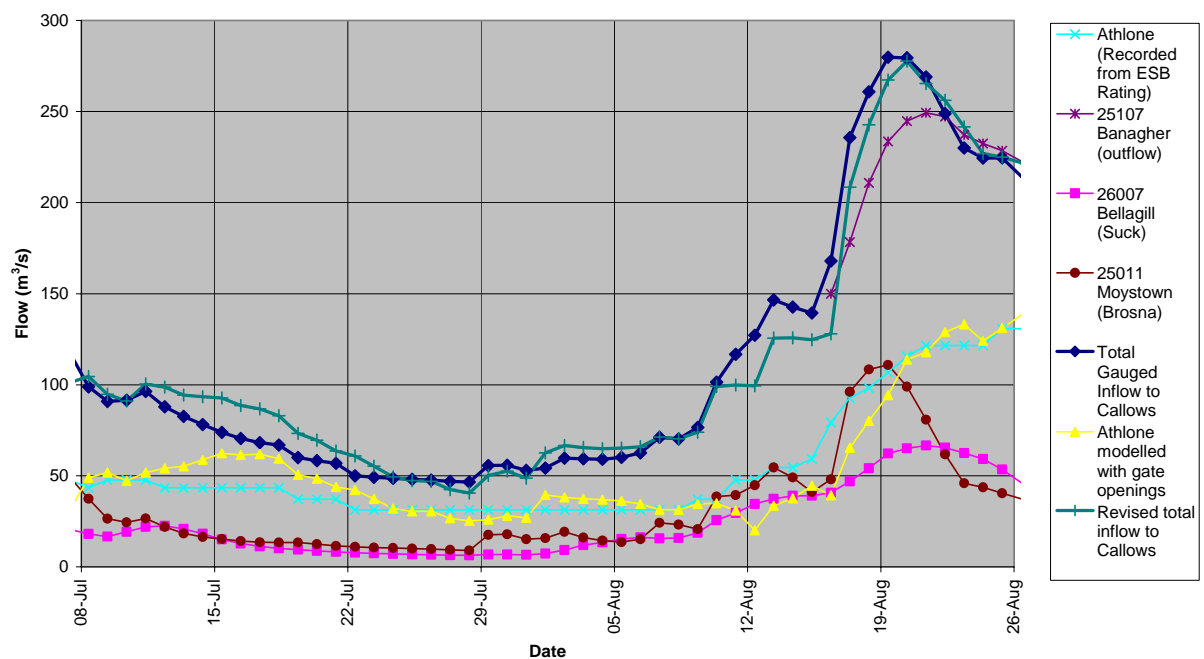
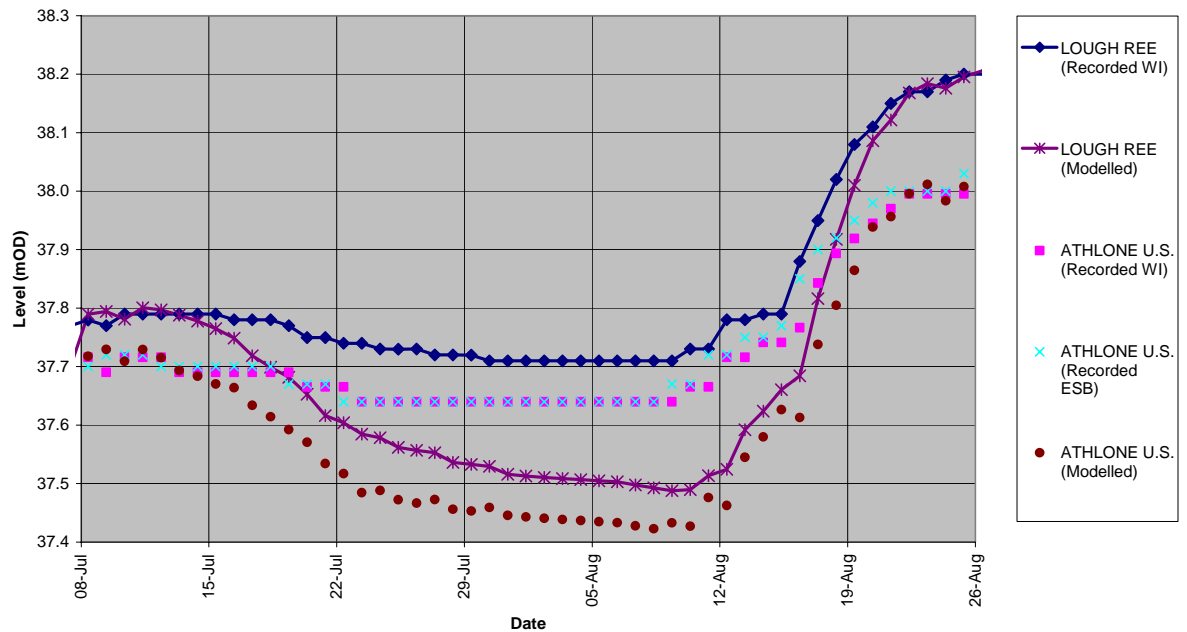


Figure 10.1 2008 Scenario (i) - Possible Impact of Lough Ree Drawdown to 37.59 mOD

- Notes: 1. Banagher gauge not rated for flows below 140 m³/s
2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

Tentative 2008 Summer Levels with Lough Ree drawn down to 37.49 mOD on 10 August



Tentative 2008 Summer Flows with Lough Ree drawn down to 37.49 mOD on 10 August

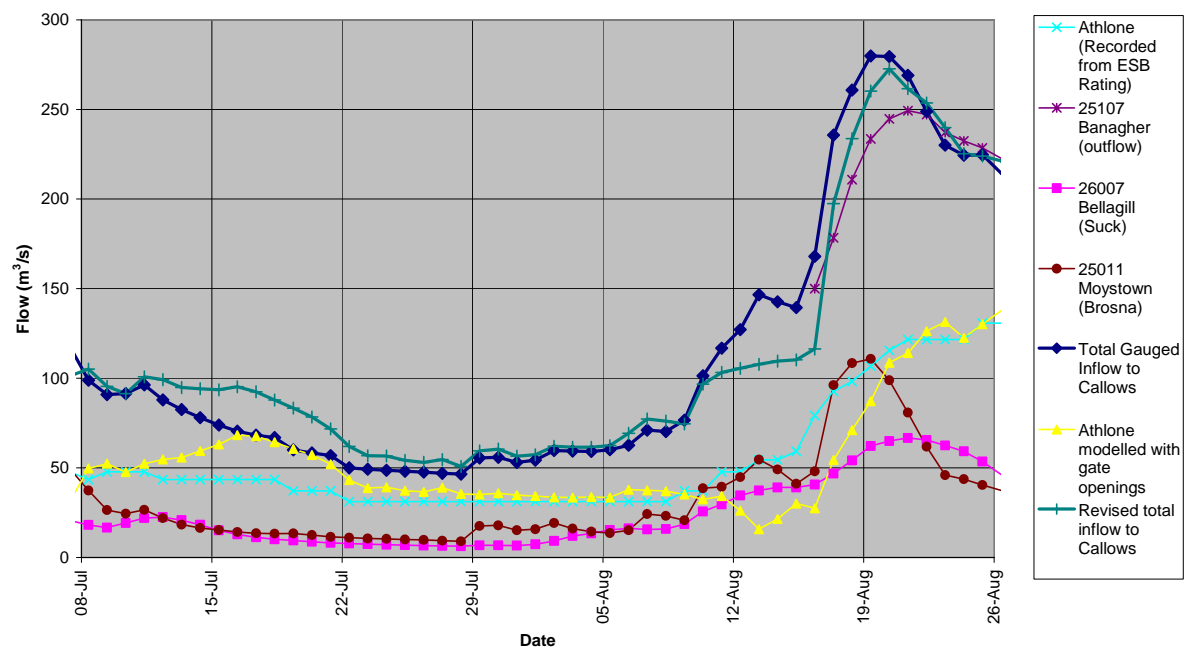
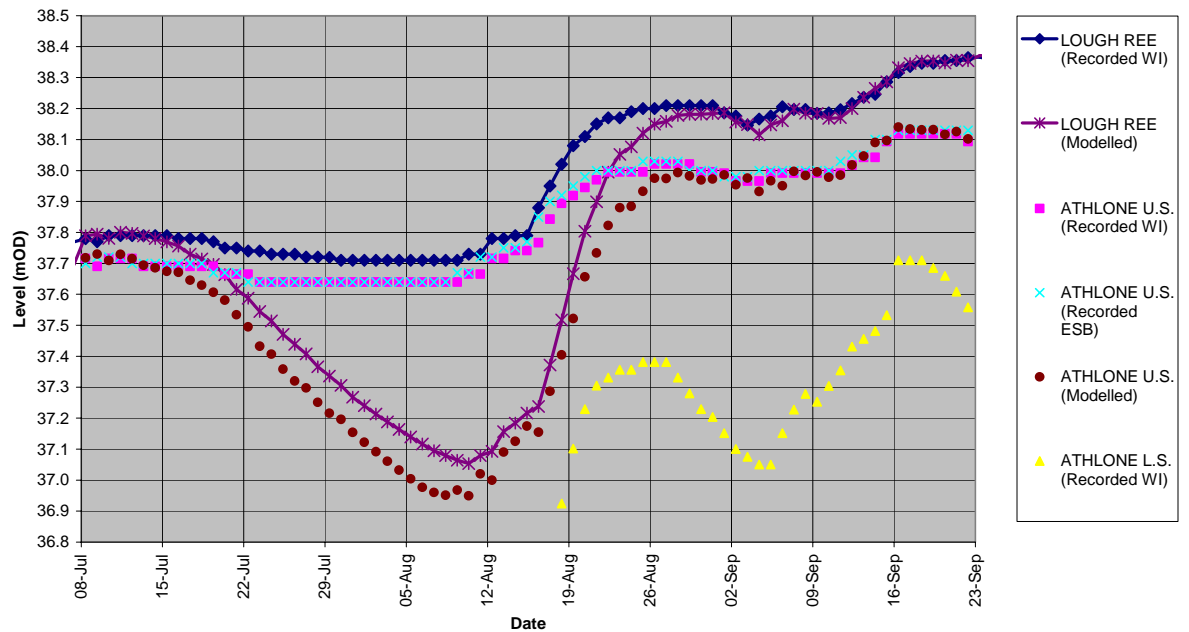


Figure 10.2 2008 Scenario (ii) - Tentative Impact of Lough Ree Drawdown to 37.49 mOD

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

Hypothetical 2008 Summer Levels with Lough Ree drawn down towards 36.88 mOD on 10 August



Hypothetical 2008 Summer Flows with Lough Ree drawn down towards 36.88 mOD on 10 August

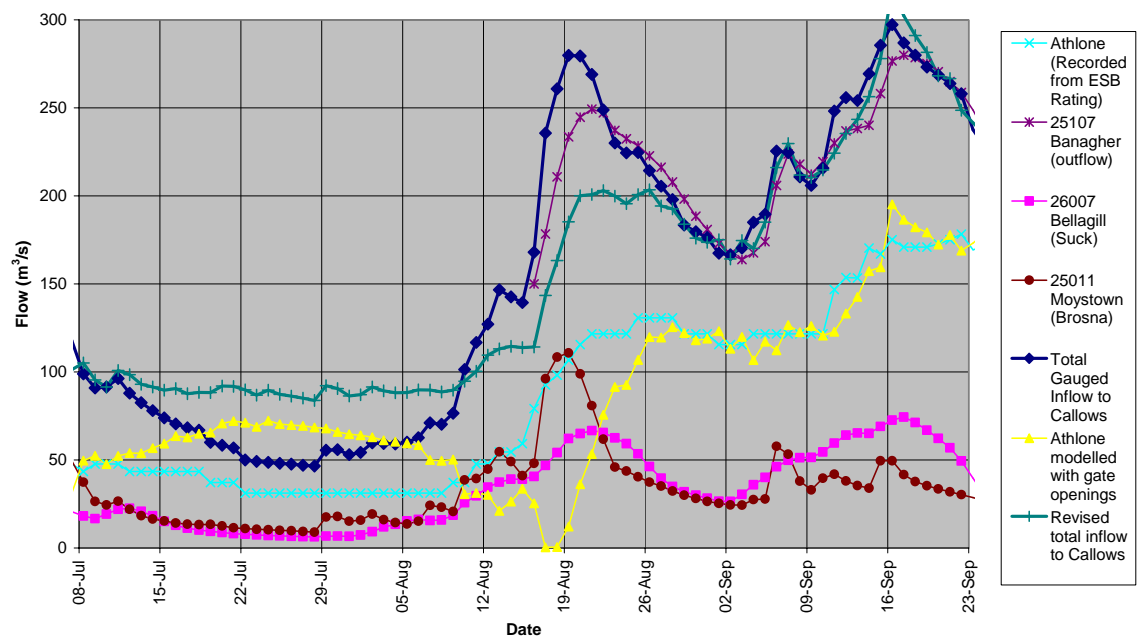


Figure 10.3 2008 Scenario (iii) - Hypothetical Impact of Lough Ree Drawdown towards 36.88 mOD

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

10.3 Impact of Alternative Operating Procedures in Summer 2009

As indicated in Section 9.5.3, there was minimal scope for drawing down Lough Ree before the early summer flood event which extended from mid April to the end of May. We have not therefore considered the impact of alternative operating procedures for this early summer flood event.

A preliminary assessment of the impact that the three operating procedure scenarios outlined in Section 10.1 may have on levels and flows in the late summer flood event of 2009 is shown on Figures 10.4, 10.5 and 10.6.

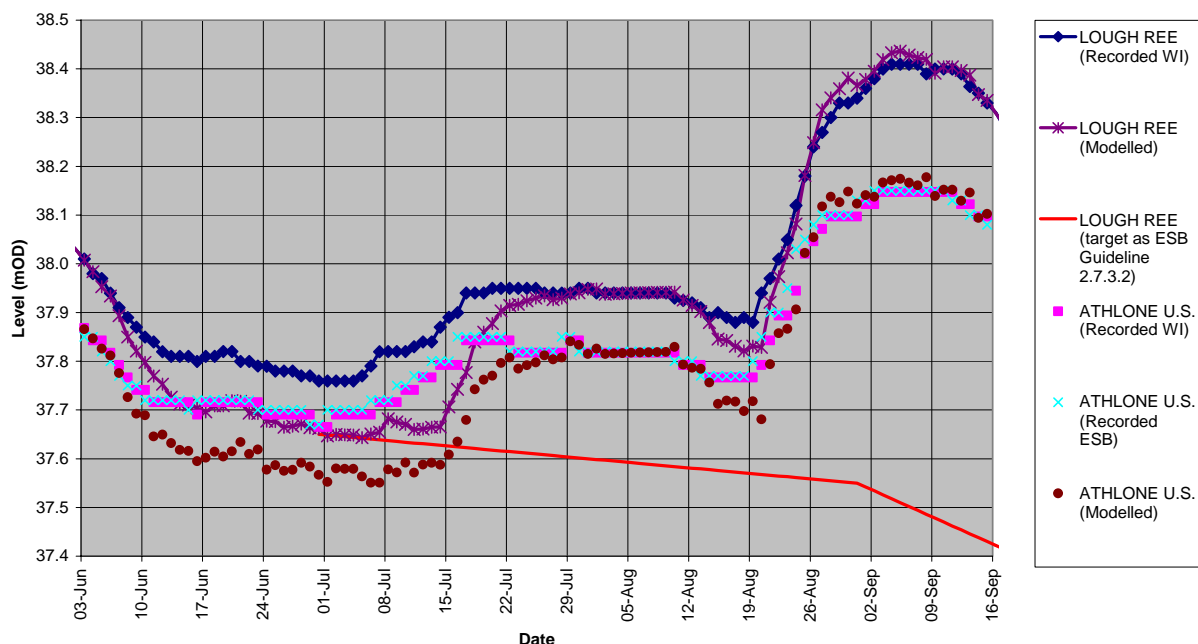
In all scenarios, sluice openings commence on 4 June, generally in increments of 1 sluice per day. More rapid opening of the sluices is likely to exacerbate waterlogging problems in the callows on the recession of the early summer flood event. Table 10.2 summarises the potential impact on flooding of the callows of the three operating procedure scenarios in the late summer flood event of 2009. In Scenarios (ii) and (iii), the moderate and extended flood inflows to the callows over the period from early July to mid August could have been controlled to largely eliminate the waterlogging effect by drawing down the storage in Lough Ree during June. However, only a marginal delay of at most a few days to the onset of flooding during the much larger event from around 20 August could have been achieved with any of these Scenarios.

Table 10.2 Potential Impact on Flooding of the Callows of Alternative Operating Procedures in 2009

Mode of Operation – drawdown level of Lough Ree before flood event	Max no. of sluices open	No. of days with stated no. of sluices open		Potential delay to onset of flooding	Notes
		> 0	> 10		
Scenario (i) 37.64 mOD – as ESB Guideline 2.7.3.2	10	54	0	< 1 day (note 3)	1
Scenario (ii) 37.49 mOD – as ESB Guideline 2.7.3.4	14	79	24	~3½ days	1
Scenario (iii) Towards 36.88 mOD – i.e. statutory Minimum Navigation Level	15	81	72	~ 4 days	1,2

- Notes: 1. Minimal impact on early September flood peak with peak gauged inflow to callows of ~280 m³/s.
2. Lowest drawdown level of Lough Ree achieved is 37.15 mOD due to discharge and downstream level constraints.
3. Potential delay up to 36 hours for a small level range at about 36.75 mOD
4. Potential delay based on perfect hindsight and ignores the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows.

Possible 2009 Summer Levels - Lough Ree drawn down on 6 July to 37.64 mOD and in mid August



Possible 2009 Summer Flows - Lough Ree drawn down on 6 July to 37.64 mOD and in mid August

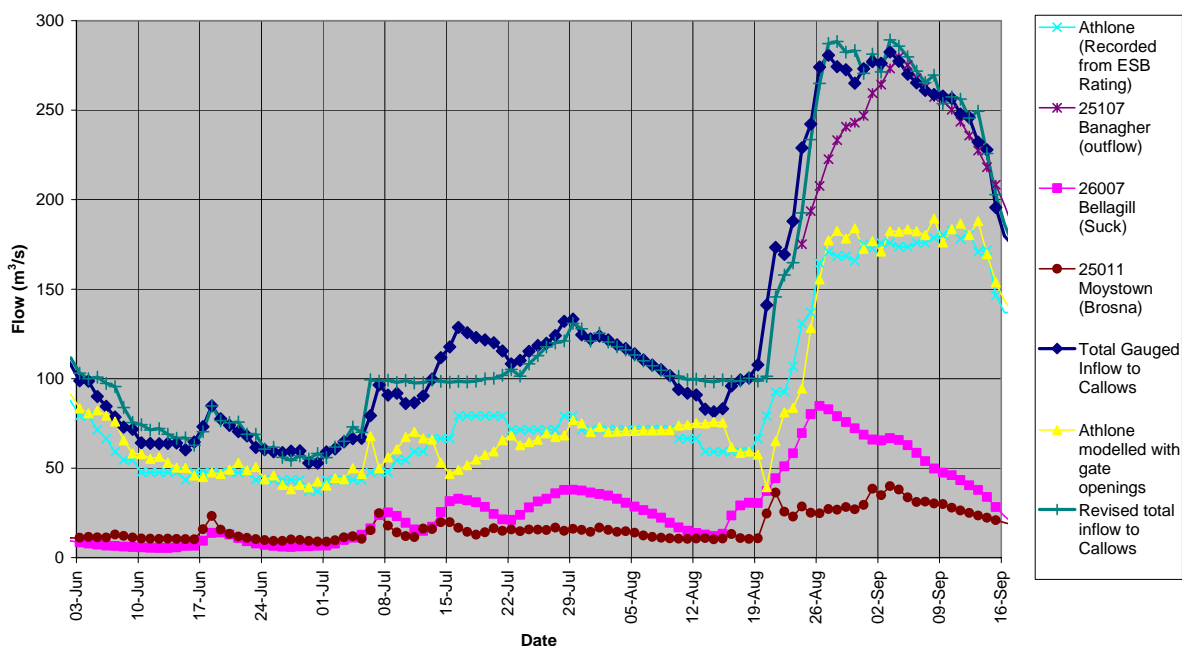
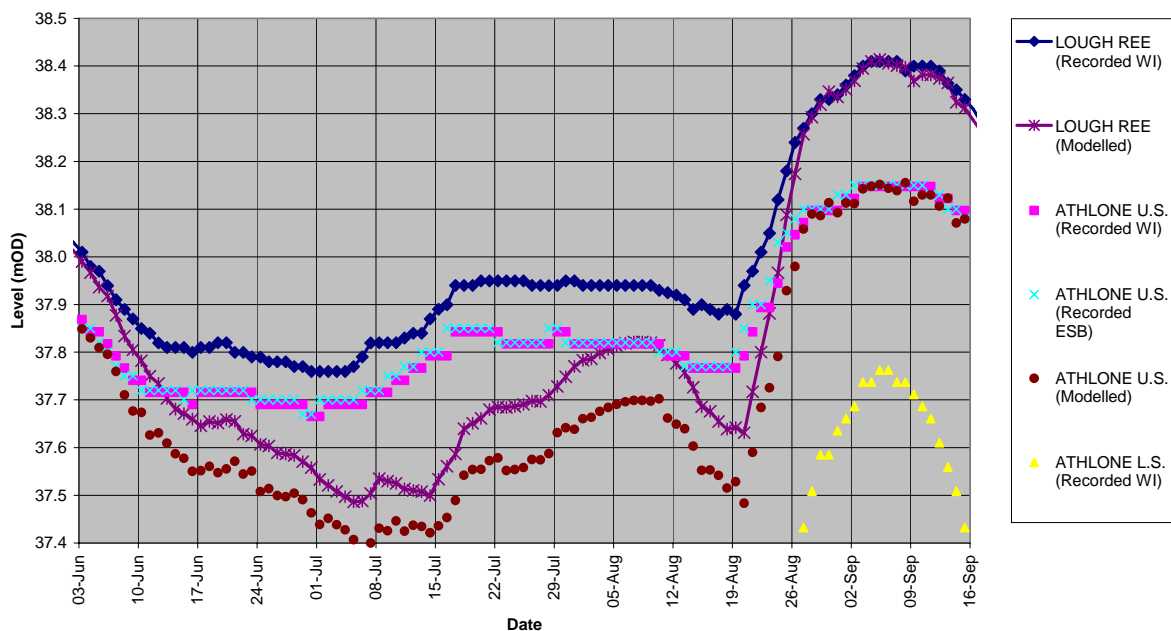


Figure 10.4 2009 Scenario (i) - Possible Impact of Lough Ree Drawdown to 37.64 mOD

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

Tentative 2009 Summer Levels - Lough Ree drawn down on 6 July to 37.49 mOD and in mid August



Tentative 2009 Summer Flows - Lough Ree drawn down on 6 July to 37.49 mOD and in mid August

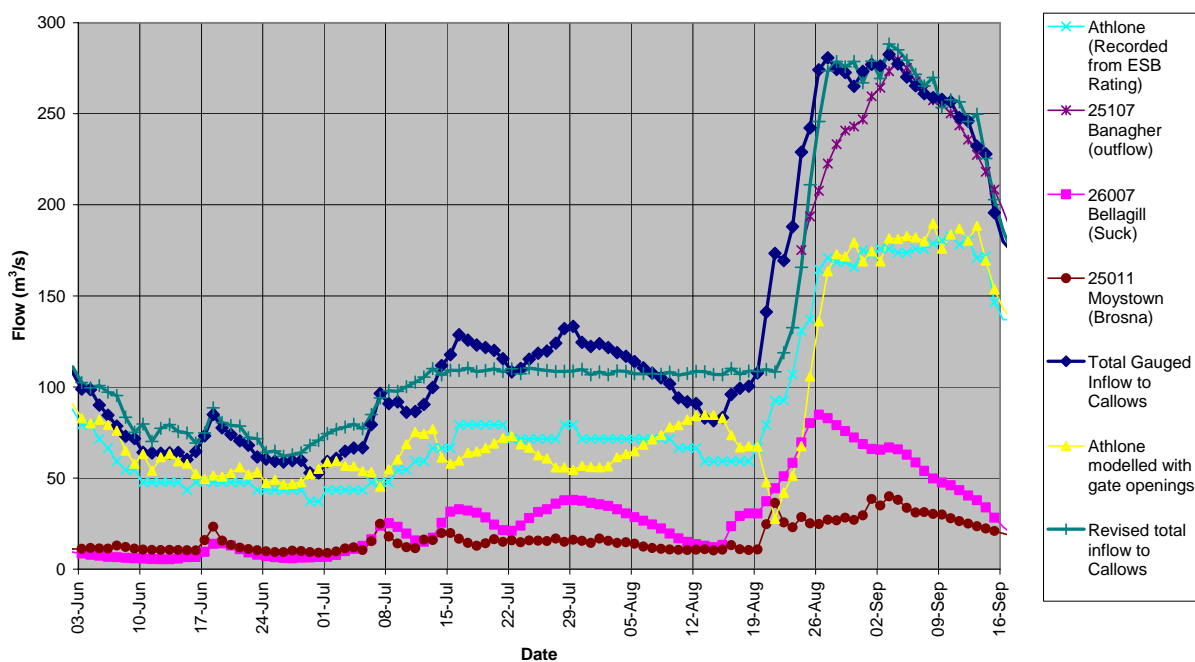
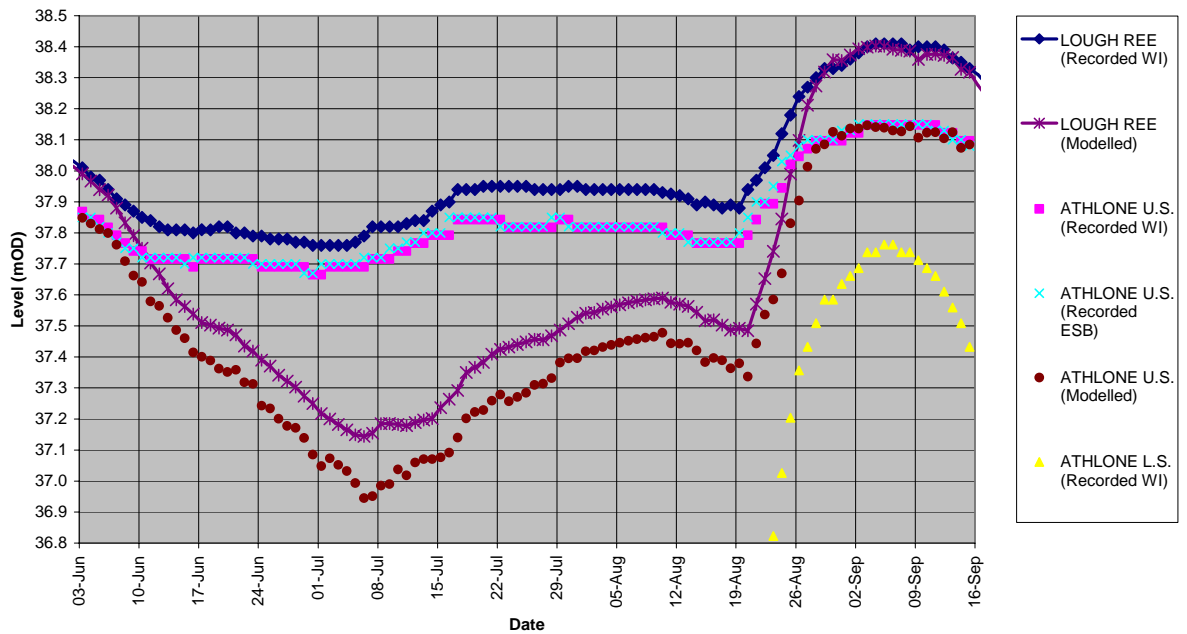


Figure 10.5 2009 Scenario (ii) - Tentative Impact of Lough Ree Drawdown to 37.49 mOD

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

Hypothetical 2009 Summer Levels with Lough Ree drawn down towards 36.88 mOD on 6 July



Hypothetical 2009 Summer Flows with Lough Ree drawn down on 6 July towards 36.88 mOD

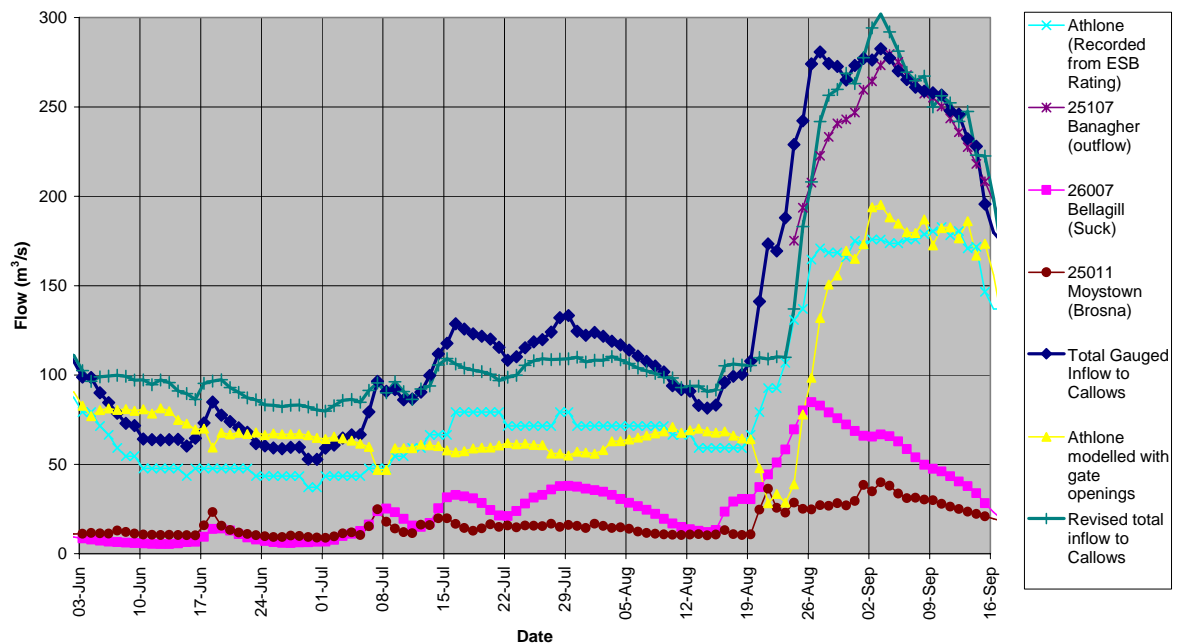


Figure 10.6 2009 Scenario (iii) - Hypothetical Impact of Lough Ree Drawdown towards 36.88 mOD

- Notes:
1. Banagher gauge not rated for flows below 140 m³/s
 2. Critical gauged total inflow for the onset of waterlogging of the callows except on the falling limb of a flood appears to be 100 -120 m³/s and for flooding 125 – 140 m³/s.

10.4 Summary

The summers of 2008 and 2009 were particularly wet. In the absence of any reliable long term forecasting and to avoid potentially exacerbating flooding in the callows downstream of Athlone Weir, ESB exercised its discretion under the Guidelines, taking account of water levels, flows, recent rainfall, Met Eireann weather forecasts and ESB's forecasting model, not to open the sluices.

The foregoing theoretical analyses (which were carried out with the benefit of perfect hindsight and assumed that the level in Lough Ree was drawn down as far as possible towards the minimum level in the bands outlined in ESB Guideline 2.7.3.2.) estimate that the level in Lough Ree could have been drawn down by around 0.1m prior to the summer flood event of 2008 and by around 0.2m prior to the summer flood event of 2009.

In 2008, Figure 10.1 shows that opening of some sluices between 12 July and 12 August could have delayed the onset of conditions for flooding of the callows by up to 4 days for the lowest lying areas and around 1 day for the remainder. However, there would have been no reduction in either the extent of flooding or the subsequent duration.

In 2009, Figure 10.4 shows that opening of some sluices between 4 June and 18 July might have delayed the onset of conditions for waterlogging in the callows by perhaps a week, but would have had minimal impact on the levels just below the "trigger" level for flooding prevailing in early August. Some releases through the Athlone Weir sluices might possibly have been made between say 11 and 19 August, although in the absence of reliable forecasts this might have increased the risk of exacerbating waterlogging and/or flooding downstream if the flood event had evolved differently. Such sluice openings could have delayed the onset of conditions for flooding of the callows by less than a day, other than for a small level range at about 36.75 mOD where the delay might have been up to 36 hours. However, there would have been no reduction in either the extent of flooding or the subsequent duration.

Figures 10.2 and 10.5 show the tentative impact of drawing down Lough Ree rather further prior to the flood events of 2008 and 2009 to the currently adopted minimum normal operating level of 37.49 mOD for the early summer period. These Figures and the summary data in Tables 10.1 and 10.2 indicate that the additional benefit in terms of reduced impact on waterlogging and flooding for the particular conditions experienced in 2008 and 2009 would be relatively small. With this mode of operation drawdown is required over an extended period of a month or more, so, unless a reliable long term weather forecast was to become available, there would be an increased risk of low water levels towards the end of a dry summer.

Similarly Figures 10.3 and 10.6 show the hypothetical impact of drawing Lough Ree down further prior to the flood events of 2008 and 2009 towards the statutory Minimum Navigation Level of 36.88 mOD. Again these Figures and the summary data in Tables 10.1 and 10.2 indicate that the additional benefit in terms of reduced impact on waterlogging and flooding for the particular conditions experienced in 2008 and 2009 would be relatively small. With this mode of operation, there would be a greater risk of low water levels towards the end of a dry summer.

11

Conclusions and Recommendations

11.1 Conclusions

11.1.1 Historical perspective

From the literature review and study into the history of the River Shannon's development it is clear that the periodic flooding of the callows has been a regular occurrence for many centuries. Particular concerns were raised during the mid-nineteenth century following the construction of the principal navigation locks and weirs in the 1840s. As a consequence a series of flood mitigation measures were implemented in the 1880s including the construction of the New Cut at Meelick, the introduction of sluices in the original fixed weirs and new control works at Bellantra, the outlet of Lough Allen.

The implementation of the Shannon Hydro-electric Scheme in 1929 recognised the potential impact on flooding. Works at Killaloe, Parteen Weir and the Ardnacrusha Power Station effectively converted Lough Derg into a regulating lake. Embankments and pumping stations were installed on the west bank between Meelick and Portumna to reduce flooding of the callows in this area. The new sluices at Bellantra increased the regulating range of Lough Allen from 1938, primarily to enhance low flows, but with some benefit to the upper part of the catchment in terms of reducing outflows in flood periods.

The principal area with the greatest concerns relating to the impact of water level control operations on flood risk is the callows between Athlone Weir and Banagher. Generally the Irish Farmers Association (IFA) accepts that farmland within the floodplain is liable to flooding in the winter; it is summer flooding and any flooding potentially exacerbated by the operation of control structures on the River Shannon that is the primary cause for concern. Particular concern has been expressed over late summer (i.e. 16 August to 30 September) flooding in the callows which can have a major impact on damage to the crop before it is harvested.

11.1.2 Hydrological and hydraulic considerations

Analysis of the recorded levels at Athlone for the late summer period (16 August – 30 September) over the 80 years since 1932 shows that the incidence of downstream water levels which result in waterlogging and flooding of the callows has varied between decades, with a low of only two years out of 10 between 1992-2001 and a high of 7 or 8 years out of 10 between 1942-1951.

There is a marked increase in the frequency of occurrence of downstream water levels which result in waterlogging and flooding in the callows between the low decade of 1992-2001 and the most recent period (2002-2010), with both the number of years and the number of days increasing threefold or more. However, the recent period is no worse than 1942-51 and 1952-61.

This analysis confirms the perception that late summer flooding in the last decade has been significantly greater than over the previous four decades or so, but that the incidence of late summer flooding in the two decades 1942-1961 was in fact higher than the period since 2002. Correlation with August and September rainfall records shows that this pattern is likely to be a direct consequence of climatic variability. There is no evidence from this analysis that the change in operating procedures

which occurred in 1972, and which affects drawing down the storage in Lough Ree, has had a direct impact on the frequency of late summer flooding in the callows.

Downstream inflows, primarily from the Suck, have a significant influence on the onset of flooding in the callows. The flow hydrographs for the Suck and the Brosna confirm that, during the rising limb of a flood, the proportion of the total gauged inflow to the callows from the Suck and the Brosna rises to over 40%, compared with a typical figure of 20-25% in non-flood periods. In August 2008 this proportion in fact rose above 60%.

To avoid exceeding a downstream level of 36.12 mOD (the summer period waterlogging constraint), discretionary control of the level of Lough Ree by opening of the sluices at Athlone can generally only be achieved when the outflow from Lough Ree drops below about 70-80 m³/s, corresponding to a level of about 37.9 mOD. Above this level therefore Lough Ree effectively acts as an unregulated lake. Below this level the scope for regulation is severely constrained by both the naturally high lake levels in relatively wet summers and the ESB guidelines for limiting drawdown to ensure adequate water levels towards the end of dry summers.

The starting level of Lough Ree has no impact on flood extents during the peak of the event. The increased storage due to lower levels would be very small in comparison to the volume of the hydrograph leading up to the subsequent flood peak. Moreover, if the level of Lough Ree were to be drawn down further, subsequent outflows on the rising flood would be reduced due to the fixed hydraulic characteristics of Athlone Weir. Hence more of the volume of the rising flood would be retained in Lough Ree, thus effectively “losing” the increased storage before the peak of the event is reached.

11.1.3 Weir and sluice operation during recent summer floods

Examination of the Waterways Ireland (WI) records of sluice openings at Meelick Weir and the New Cut and comparison with level records at Athlone over the summers of 2007 to 2010 confirms that the periods when all 30 sluices were fully opened coincides almost exactly with periods when the downstream level at Athlone exceeds the 36.12 mOD “trigger” level for potential waterlogging of the callows. The records also indicate that, where they were in place before the event, the weir boards were all removed in a timely manner. Hence we confirm the conclusions of previous reports that sluice operations at Meelick and the New Cut have no adverse impact on flooding in the callows, provided Waterways Ireland operate the sluices and remove the weir boards in accordance with the normal procedures.

The summers of 2008 and 2009 were particularly wet. In the absence of any reliable long term forecasting and to avoid potentially exacerbating flooding in the callows downstream of Athlone Weir, ESB exercised its discretion under the Guidelines for the control of the River Shannon, taking account of water levels, flows, recent rainfall, Met Eireann weather forecasts and ESB’s forecasting model, not to open the sluices.

The theoretical analyses described in Section 9.5 were carried out with the benefit of perfect hindsight (i.e. ignoring the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the callows at the 36.12 mOD trigger level for waterlogging). They assume that the level in Lough Ree could be drawn down as far as possible towards the minimum level in the bands outlined in ESB Guideline

2.7.3.2 and estimate that the level in Lough Ree could have been drawn down, but only by around 0.1m prior to the summer (August) flood event of 2008 and by around 0.2m prior to the summer (July-August) flood event of 2009.

In 2008 opening of some sluices between 12 July and 12 August in accordance with the ESB Guideline 2.7.3.2 could have delayed the onset of conditions for flooding of the callows by less than 1 day other than in the lowest lying areas where it could have been up to 4 days. However, there would have been no reduction in either the extent of flooding, which reached a maximum level of 37.68 mOD on 17-19 September (i.e. 1.26m above the “trigger” level for flooding of 36.42 mOD) or the total duration of flooding with levels remaining very high right through into the winter period.

In 2009 opening of some sluices between 4 June and 18 July in accordance with the ESB Guideline 2.7.3.2 might have delayed the onset of conditions for waterlogging in the callows by perhaps a week, but would have had minimal impact on the levels just below the “trigger” level for flooding prevailing in early August. Some releases through the Athlone Weir sluices might possibly have been made between say 11 and 19 August, although in the absence of reliable forecasts this might have increased the risk of exacerbating waterlogging and/or flooding downstream if the flood event had evolved differently. Such sluice openings could have delayed the onset of conditions for flooding of the callows by less than a day, other than for a small level range at about 36.75 mOD where the delay might have been up to 36 hours. However, there would have been no reduction in either the extent of flooding which reached a maximum level of 37.73 mOD on 4-5 September (i.e. 1.31m above the “trigger” level for flooding of 36.42 mOD) or the total duration of flooding with levels remaining above the 36.42 mOD “trigger” level until 28 September.

Throughout the summer of 2010, which was considerably drier than the three preceding summers, the operation of the sluices at Athlone Weir was controlled to follow the minimum prescribed levels in ESB Guideline 2.7.3.2. Within the existing Guidelines there was no scope for increasing the available flood storage in Lough Ree prior to the rapid rise in inflows to the callows from 7 September. Hence, within the constraints of Guidelines, the timing of the subsequent waterlogging of the callows over the next two days could not have been significantly influenced by alternative modes of operation of the sluices at Athlone. With the continuing rise in inflows there could have been no impact at all on either the subsequent maximum extent or duration of the flooding of the callows which extended for some 4½ weeks until 9 October.

As a result of our analysis it can be concluded that whether sluices at Athlone are opened in advance of a flood or not only has a marginal effect on the timing of a summer flood but has no influence on the extent or duration of the flooding.

11.1.4 Potential changes to Athlone Weir operating procedures

We have provided a tentative indication of the impact of drawing down Lough Ree further than ESB Guideline 2.7.3.2 currently allows prior to the flood events of 2008 and 2009 to the currently adopted minimum normal operating level of 37.49 mOD for the early summer period and also a hypothetical indication of the impact of allowing drawdown to the statutory Minimum Navigation Level of 36.88 mOD. These theoretical analyses were again carried out with the benefit of perfect hindsight (i.e. ignoring the practical limitations of accurately forecasting inflows to the callows and co-ordinating sluice operations at Athlone Weir to maintain a steady level in the

callows at the 36.12 mOD trigger level for waterlogging) and indicate that the potential additional benefit (i.e. compared to operation in accordance with ESB Guideline 2.7.3.2) in terms of reduced impact on flooding for the particular conditions experienced in 2008 and 2009 would be relatively small, delaying flooding by no more than a further day in 2008 and possibly 3 days in the atypical summer flood event of 2009. With these modes of operation drawdown is required over an extended period of a month or more, so, unless a reliable long term weather forecast was to become available, there would be an increased risk of low water levels towards the end of a dry summer.

11.2 Recommendations

This Technical Assessment: River Shannon Level Operation Review summarises the history of developments on the Shannon and an extensive range of earlier reports covering most of the last 200 years.

The recommendations are divided into two different categories:

1. Immediate or Short Term Actions

- In the short term, operation of the Athlone Sluices should continue to follow ESB Guideline 2.7.3.2. ESB Guideline 2.7.3.2 is intended to “*optimise storage in Lough Ree for summer floods while allowing leeway to meet navigational requirements in dry years*”.

2. Issues identified that should be considered by the wider CFRAM Study

- Development of the hydrological and hydraulic modelling of the River Shannon which could be used to assess:
 - The extent to which realistic improvements in channel capacity through and downstream from the callows might reduce flood risk.
 - Whether the attenuation of flows from the Suck or Brosna could reduce flood risk through the callows.
- Once new topographic survey is available through the CFRAM process, compare river cross sections at critical locations along the Shannon with available historic cross sections to determine whether siltation has resulted in a reduction in the channel conveyance.

Appendix A Annual Analysis of Summer Flood Periods

Late summer floods at Athlone (16 Aug to 30 Sep)

Year	Days when lower level >36.12 mOD														Days when lower level >36.42 mOD
	Upper level less than														
	37.0	37.1	37.2	37.3	37.4	37.5	37.6	37.7	37.8	37.9	38.0	38.1	38.2	38.3	
1932									2	2	2	2	2	2	
1934	7	8	13	16	18	18	18	18	18	18	18	18	18	18	4
1935						1	2	2	6	6	6	6	6	6	1
1936				2	7	10	11	12	16	30	30	30	30	30	9
1937		2	3	3	3	6	7	7	7	7	7	7	7	7	
1938					3	3	3	3	14	20	20	20	20	20	7
1942									9	29	36	36	36	36	21
1943								1	10	23	31	31	31	31	19
1944									5	19	23	23	23	23	12
1946									5	7	10	17	31	31	26
1947									2	2	2	2	2	2	
1948									12	28	28	28	28	28	13
1950									3	13	24	33	45	45	41
1951									12	14	14	14	14	14	2
1953									11	21	21	21	21	21	5
1954									10	18	20	34	34	34	22
1956									2	22	46	46	46	46	43
1957			2	2	2	2	2	2	5	5	5	5	5	5	
1958										14	32	42	46	46	46
1960									2	7	36	36	36	36	33
1961									5	10	10	10	10	10	3
1962									1	5	19	20	20	20	19
1965								1	7	16	16	16	16	16	6
1967								2	6	16	28	28	28	28	21
1968						1	1	1	3	6	6	6	6	6	2
1973								3	6	6	6	6	6	6	
1974								1	4	6	9	30	30	30	29
1979							10	10	10	10	10	10	10	10	
1980							1	2	7	10	14	14	14	14	10
1981					1	1	1	2	4	5	5	5	5	5	
1985												8	44	46	46
1986										4	11	28	28	28	24
1987			2	2	2	2	2	2	2	2	2	2	2	2	
1988								1	3	6	28	30	30	30	26
1992								1	4	13	29	29	29	29	16
1999									5	5	8	15	15	15	11
2004									4	13	13	13	13	13	
2006										4	8	8	8	8	7
2007										11	15	15	15	15	10
2008										1	8	34	46	46	46
2009										5	12	21	40	40	36
2010									2	4	7	23	23	23	21
Total	7	10	20	25	36	44	58	71	224	463	675	822	919	921	637

periods with significant influence from downstream inflows (eg the Suck)

Appendix B Level and Flow Hydrographs for Recent Summers

Page

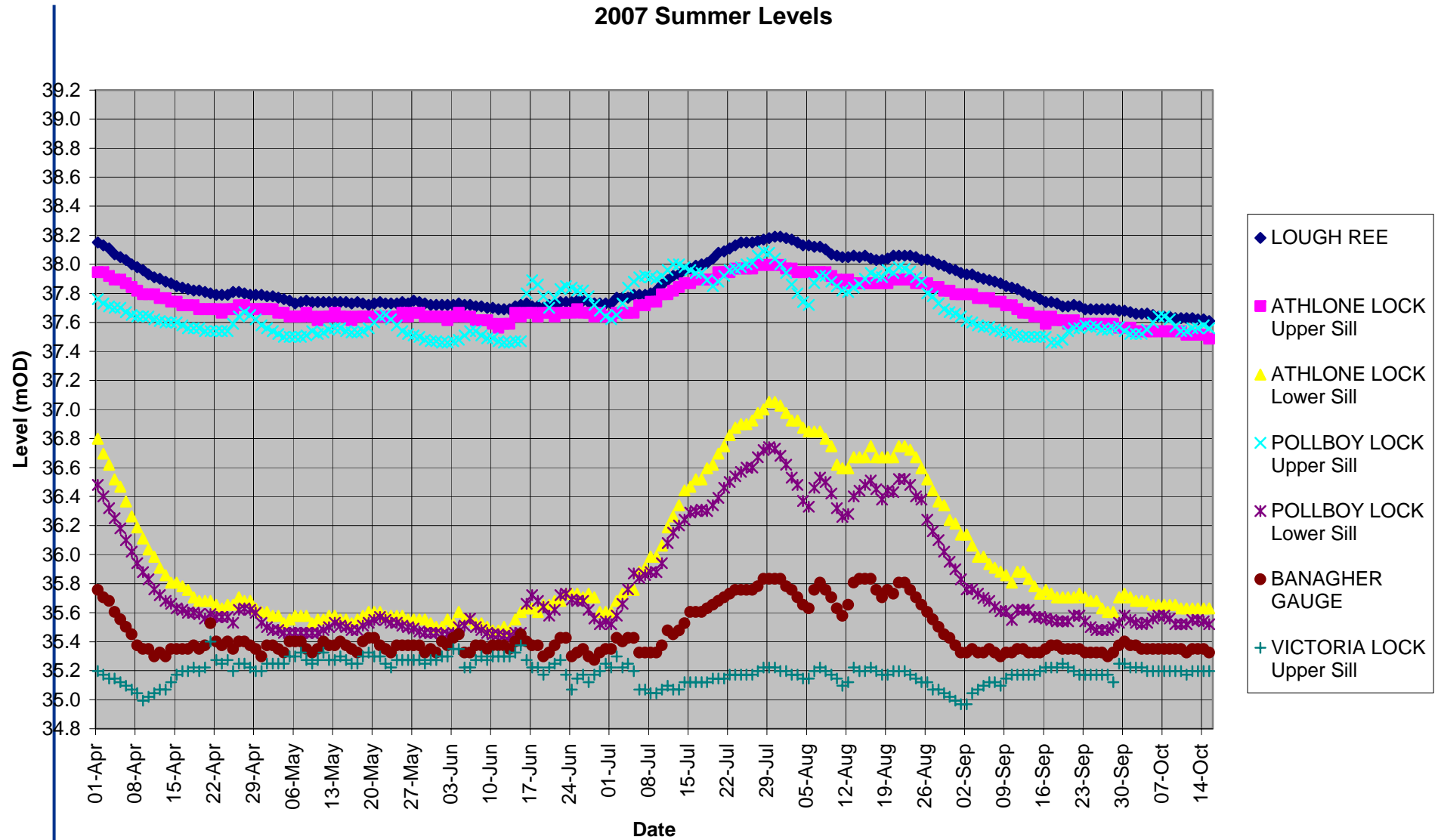
96	2007 Summer Levels
97	2007 Summer Flows
98	2008 Summer Levels
99	2008 Summer Flows
100	2009 Summer Levels
101	2009 Summer Flows
102	2010 Summer Levels
103	2010 Summer Flows
104	Relationship between Athlone downstream water level and total gauged inflow to the callows
105	Middle Shannon: Approximate level – discharge relationships

Notes on source of data for level-discharge relationships on page 105:

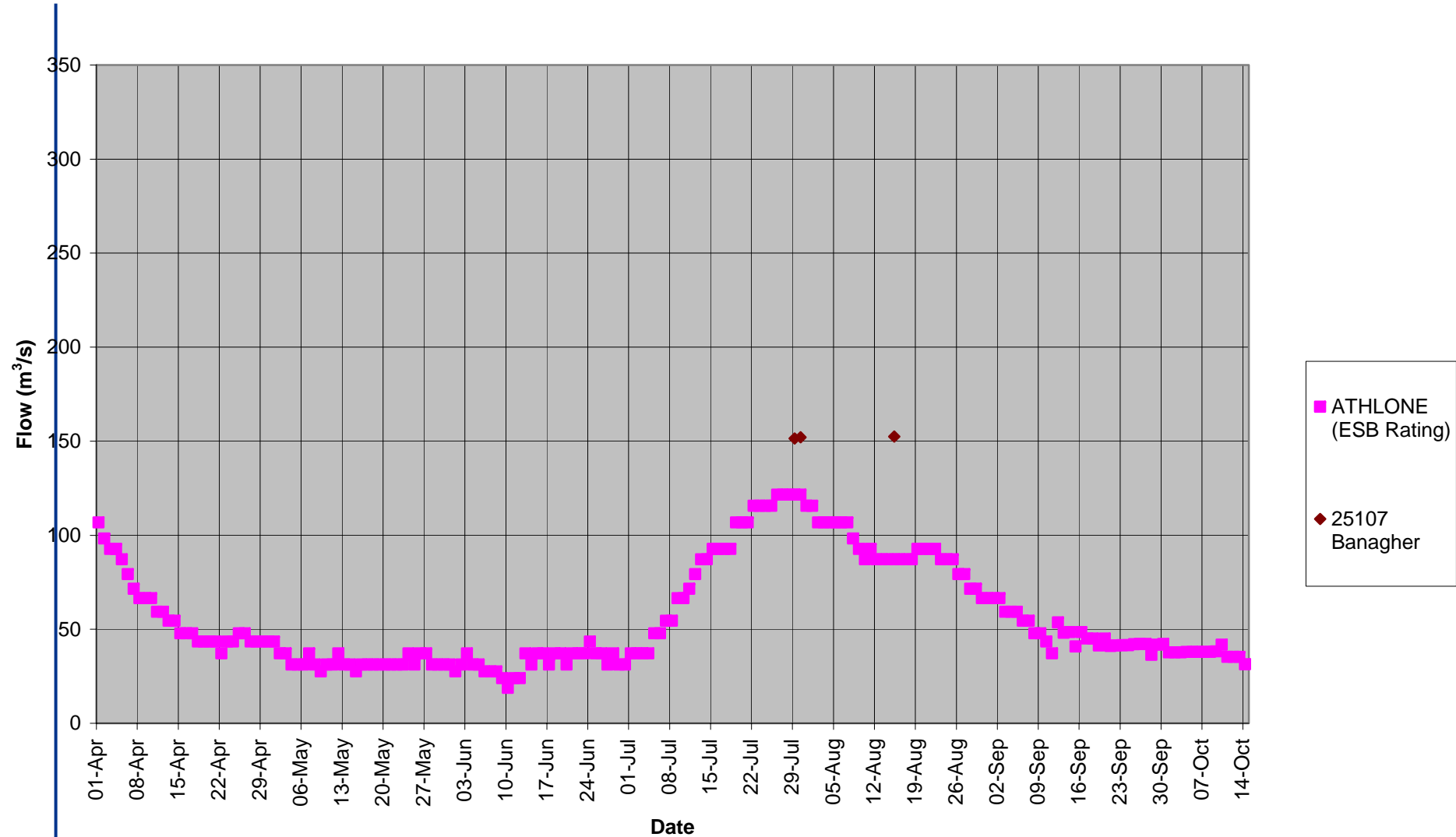
- Lough Ree: Summer period data for 2008 – 2010: WI level data; Athlone Weir discharge as below.
- Athlone Weir:
1. Discharge calculations based on ESB Preliminary Report, May 2011, Athlone Weir Discharge Equations – Revision of October 2010.
 2. Downstream water level for discharge calculation assumed based on an approximate steady state relationship with gauged total inflow to the callows and assuming 25% of this is contributed from the Suck and the Brosna (see Section 9.3).
- Athlone downstream level:
1. Discharge based on total gauged inflow to the callows
 2. Approx steady state relationship from page 104
 3. Spread derived from Summer data 2008, 2009 (Apr to 15 Oct) and 2010 (Apr to mid June), excluding flows below 40 m³/s
- Banagher: OPW records for gauge 25017 for periods in 2008-2010 when flows recorded (>140 m³/s). Flows below this can be affected by sluice and weir board operations at Meelick Weir and the New Cut.
- Meelick Weir: Data from Figures 14 and 15 in Appendix I of the ESB Regulations and Guidelines [Note: these figures are marked as “Under Revision”]

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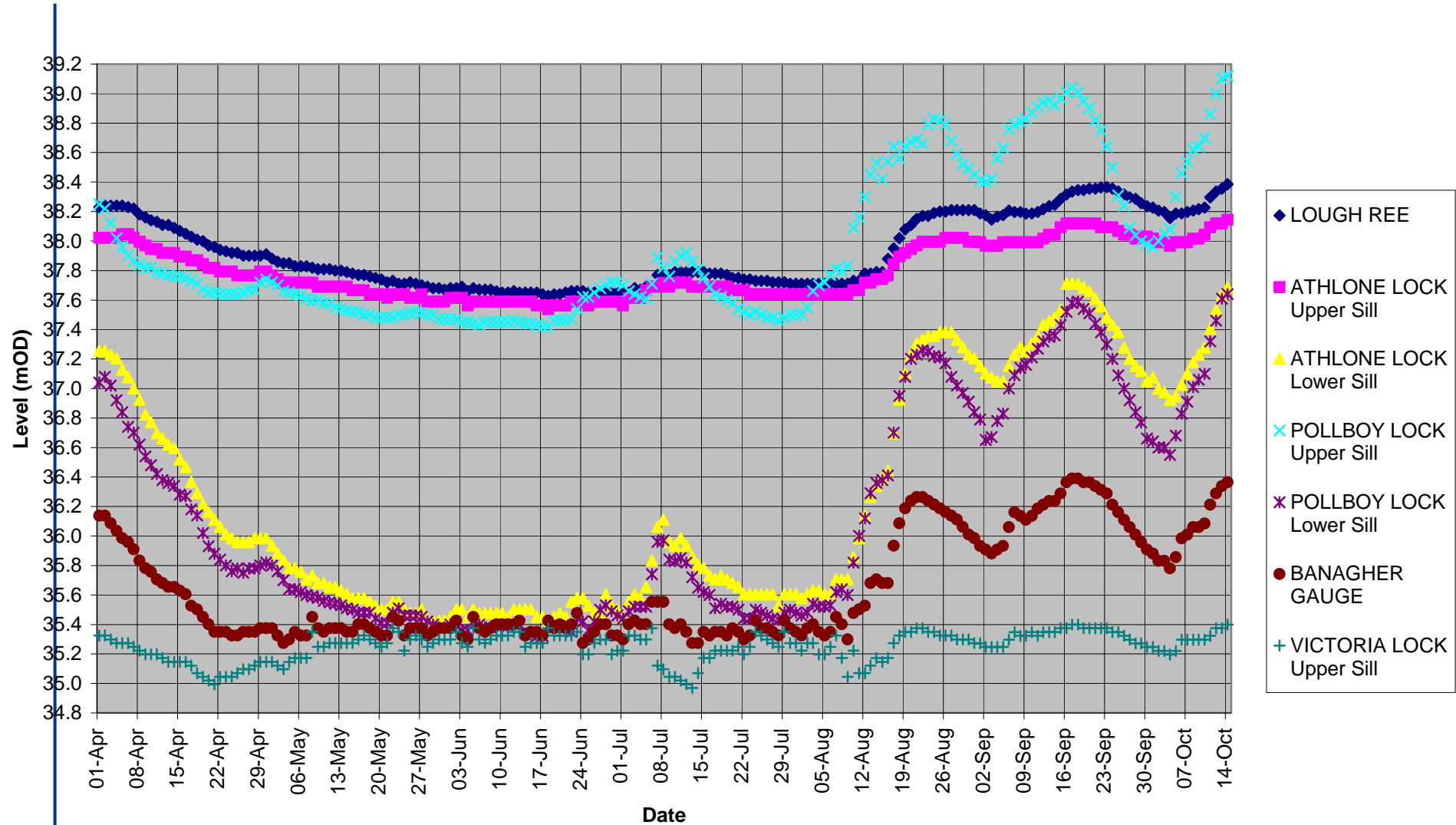
2007 Summer Levels



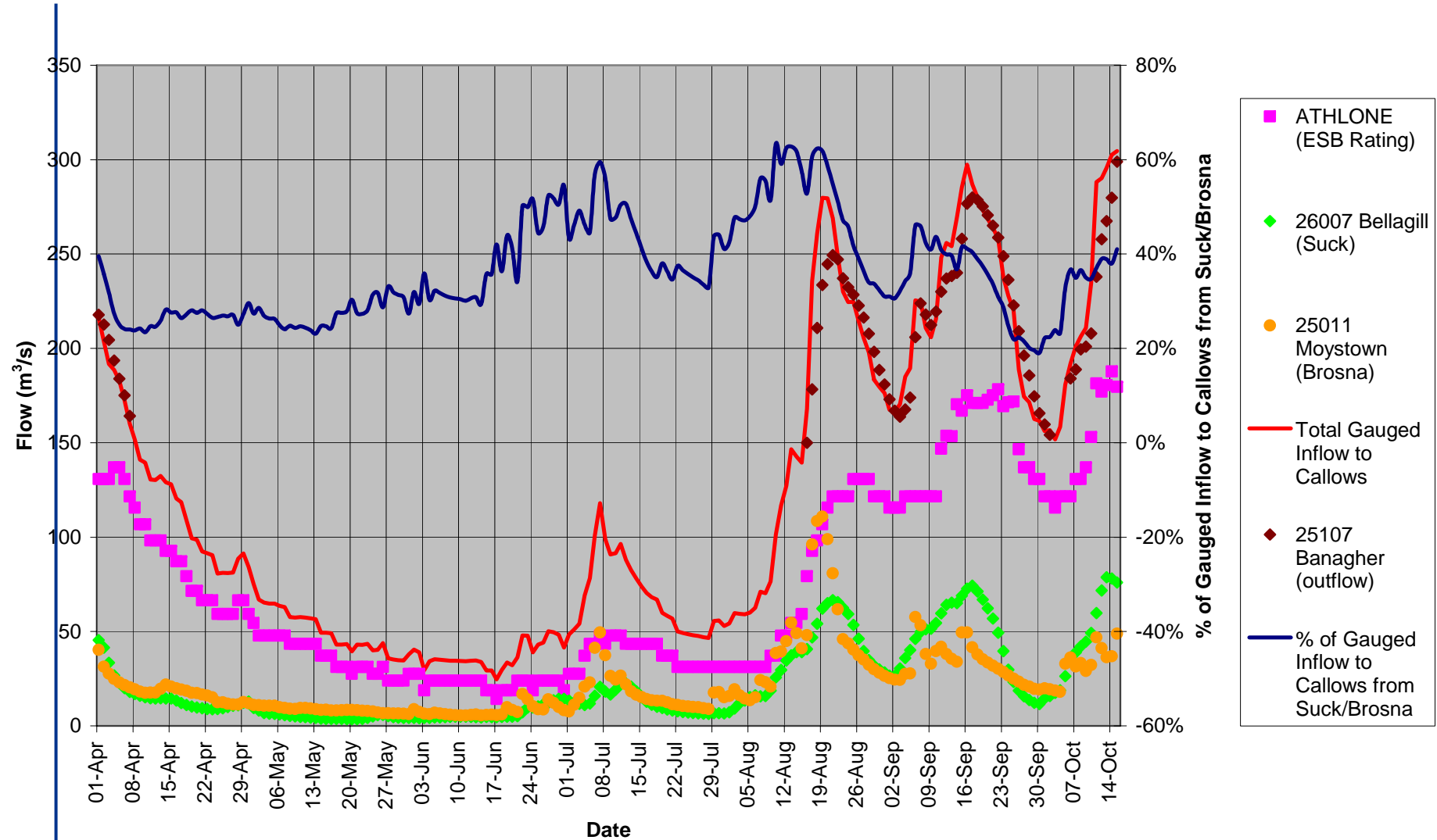
2007 Summer Flows



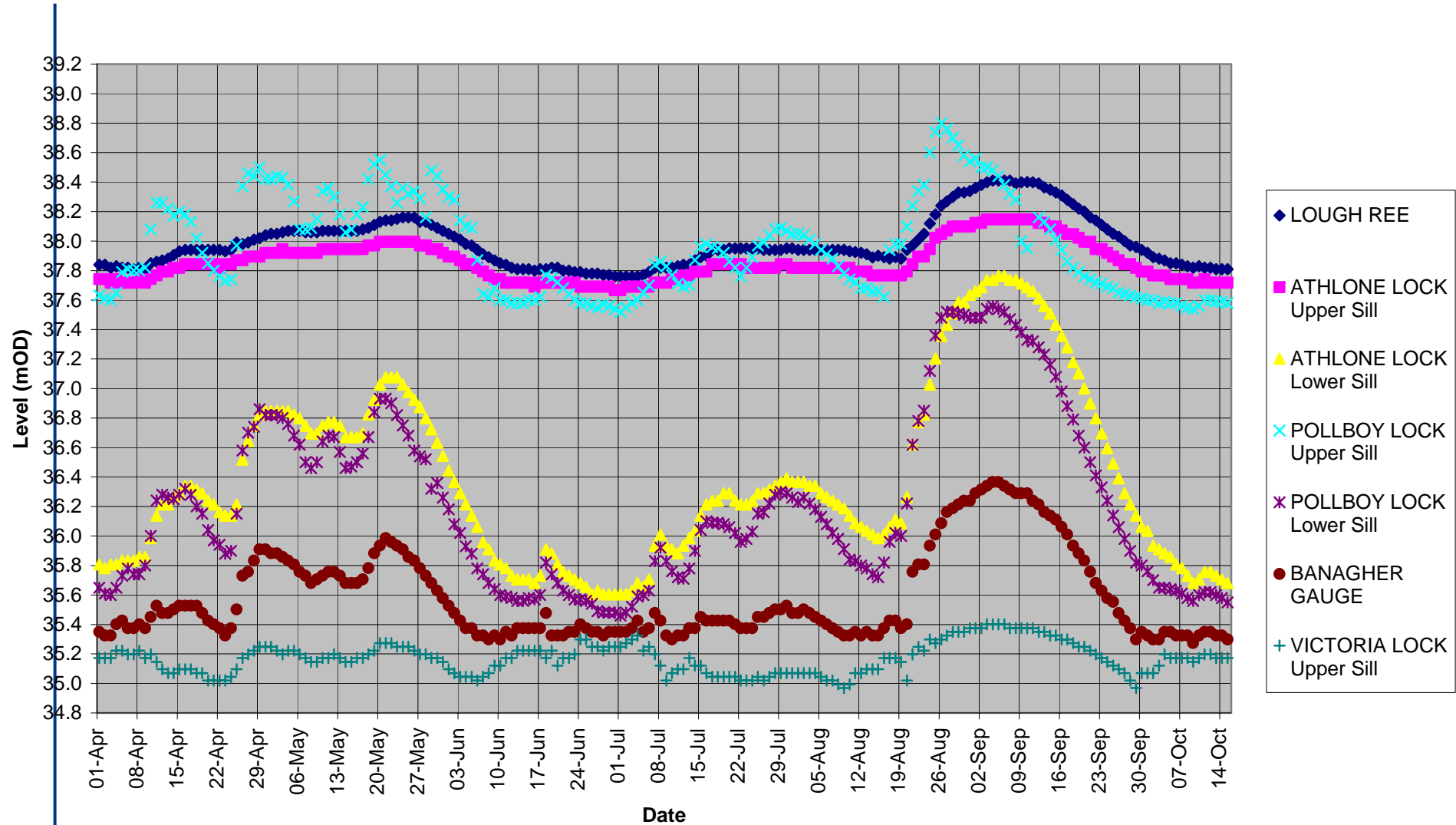
2008 Summer Levels



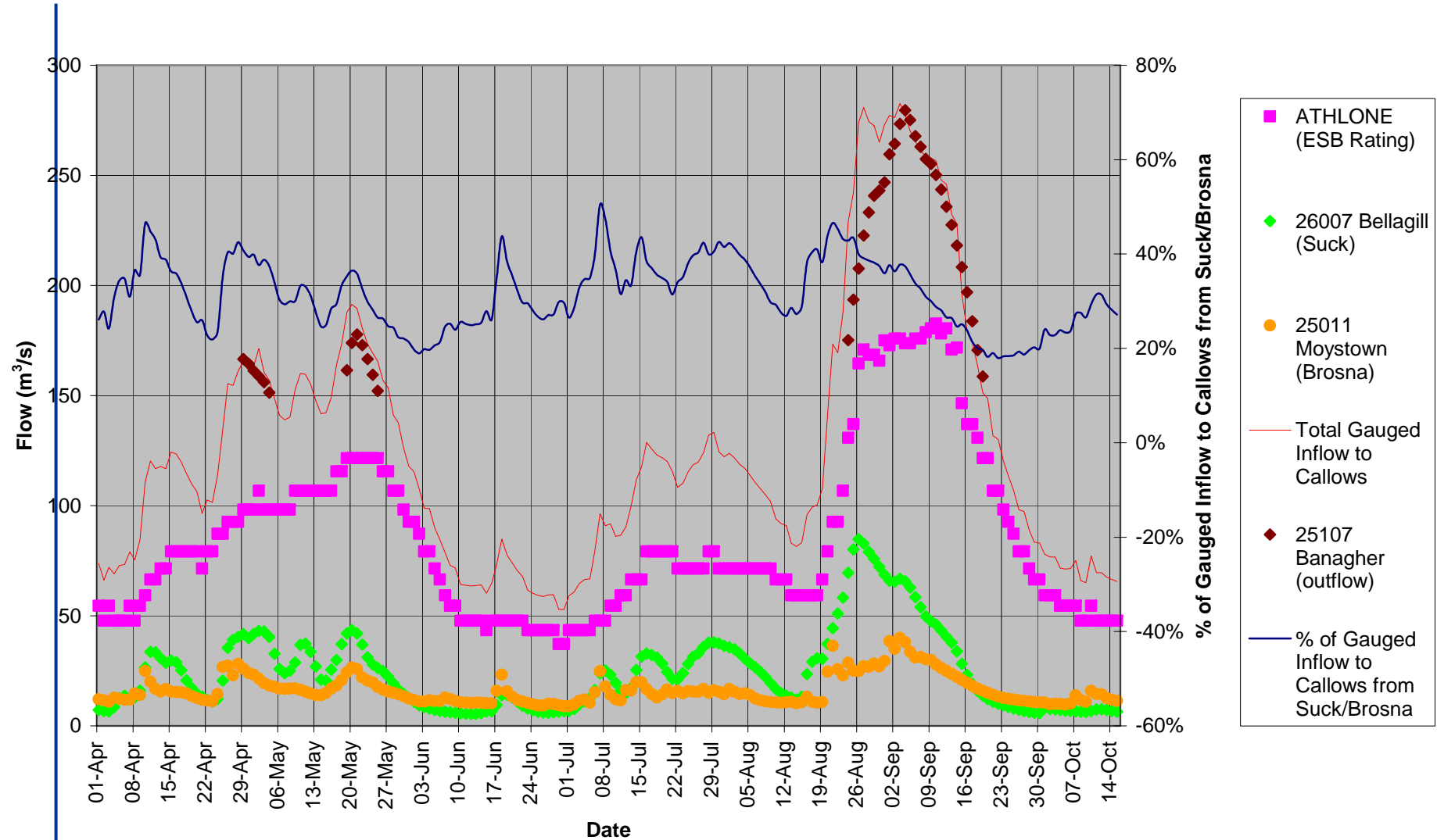
2008 Summer Flows



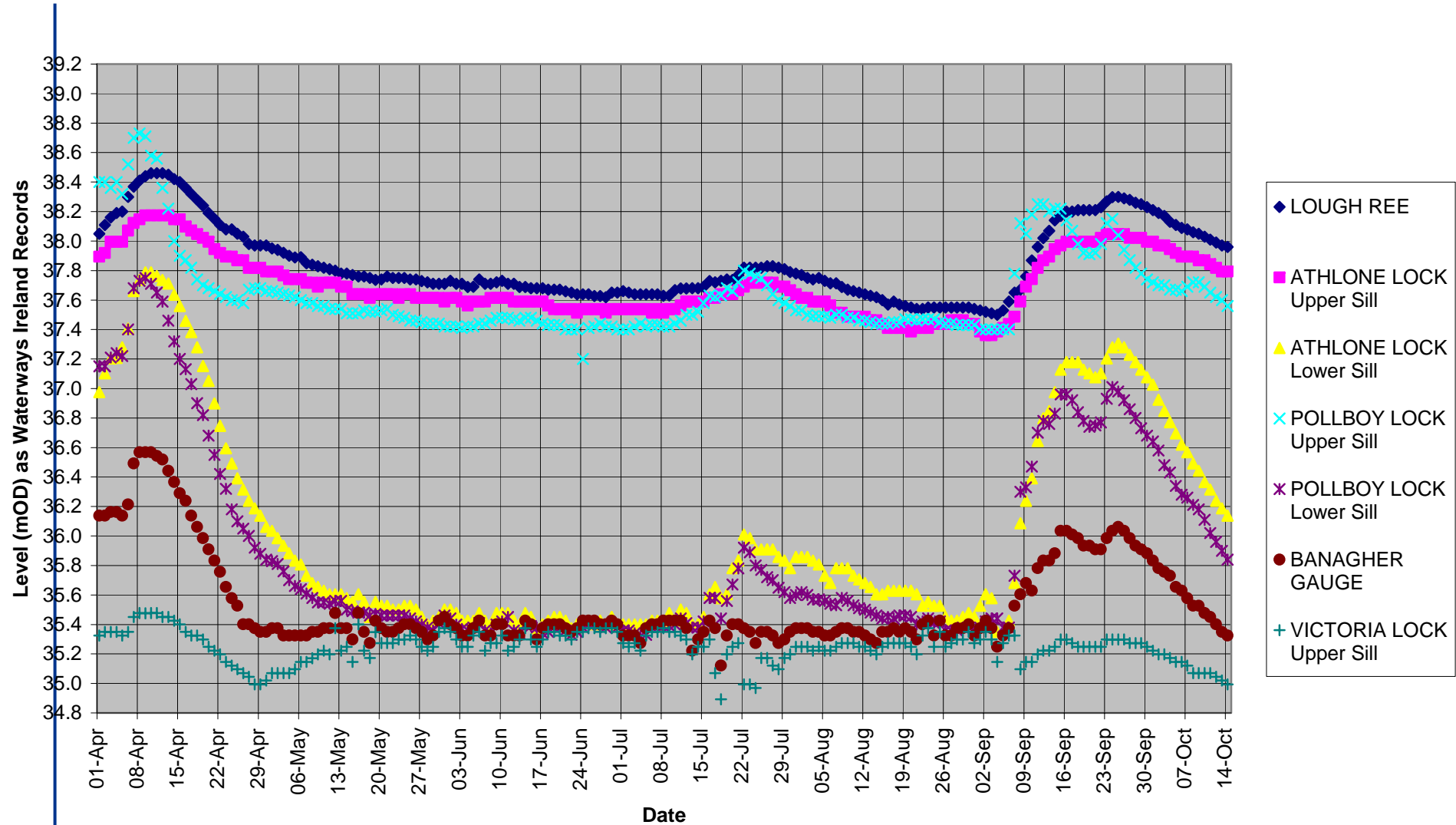
2009 Summer Levels



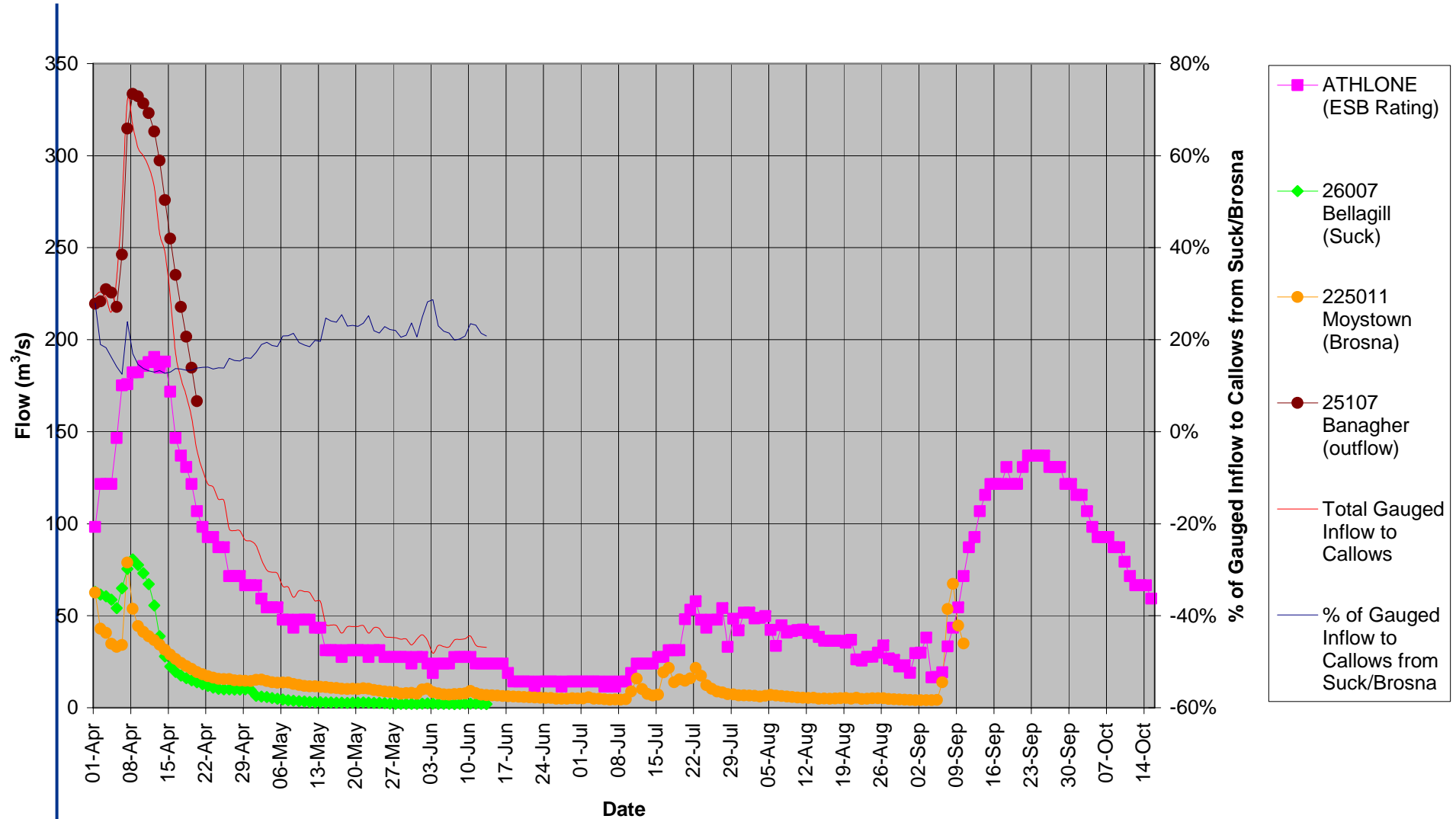
2009 Summer Flows



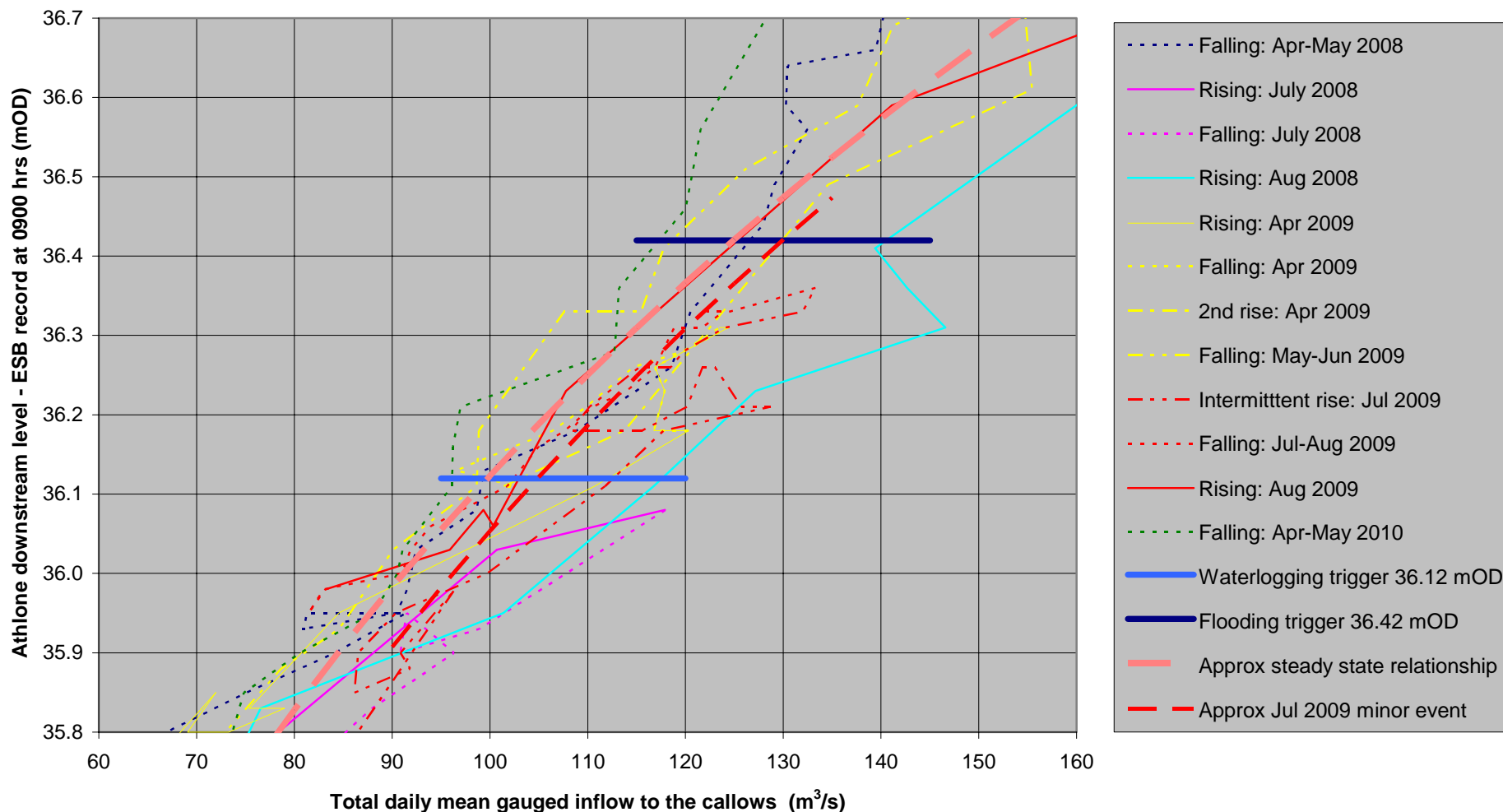
2010 Summer Levels



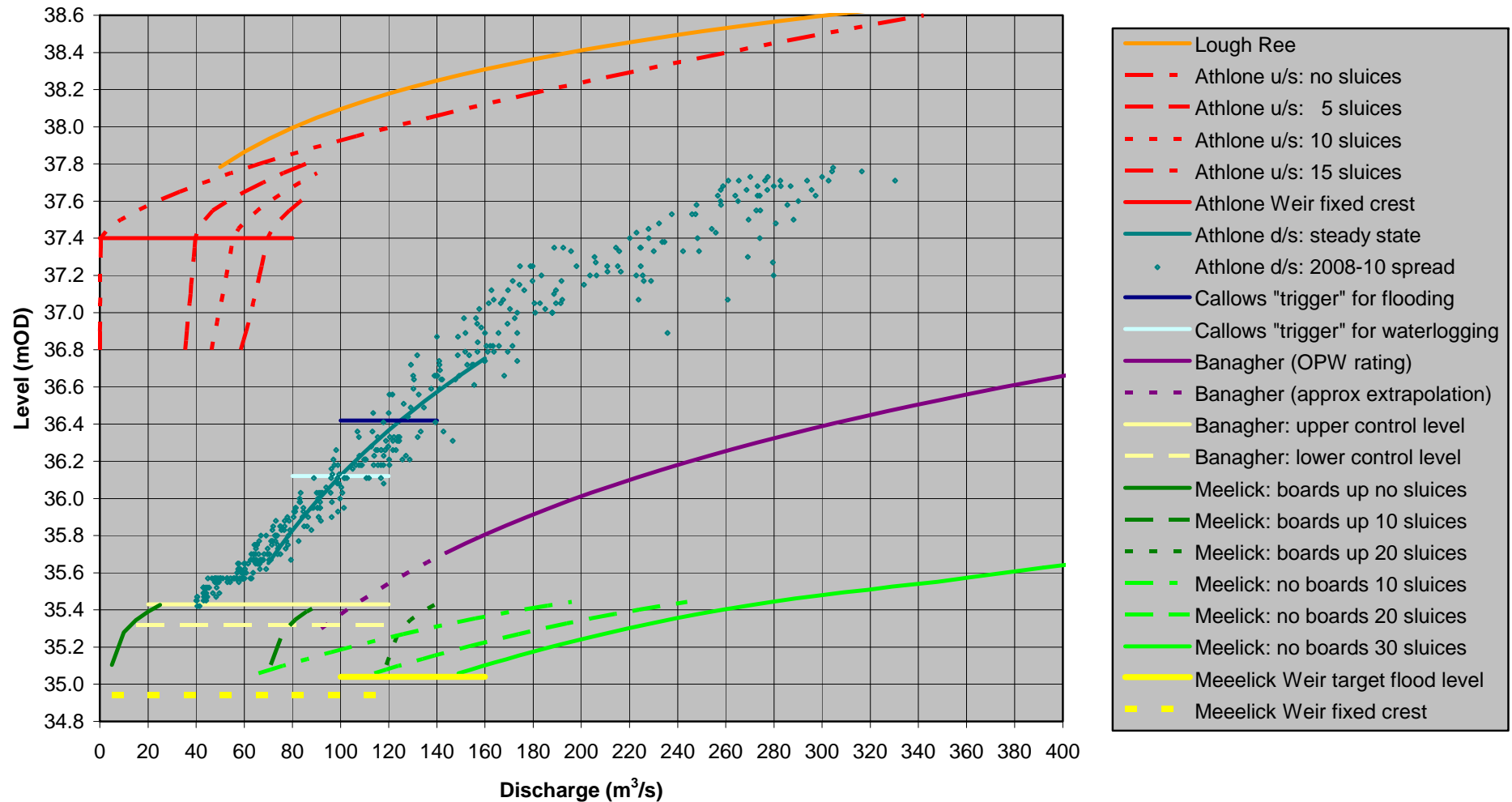
2010 Summer Flows



Relationship between Athlone downstream water level and total gauged inflow to the callows



Middle Shannon: Approximate level - discharge relationships (realistic operational ranges only)



Note: Athlone downstream levels plotted against total gauged inflow to the callows (Shannon at Athlone; Suck at Bellagill; Brosna at Moystown)