FLOOD RISK MANAGEMENT THROUGH RESERVOIR STORAGE AND FLOW CONTROL

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1. INTRODUCTION

There are fifteen large dams located throughout the Republic of Ireland. These dams and their reservoirs perform several functions including flood alleviation, water supply, electricity generation and recreation. The dams are owned by the Electricity Supply Board (ESB), Waterford County Council, Dublin Corporation and Donegal County Council. They comprise the Irish Register of Large Dams in accordance with the criteria of the International Commission on Large Dams.

There are also numerous smaller impoundments throughout the country.

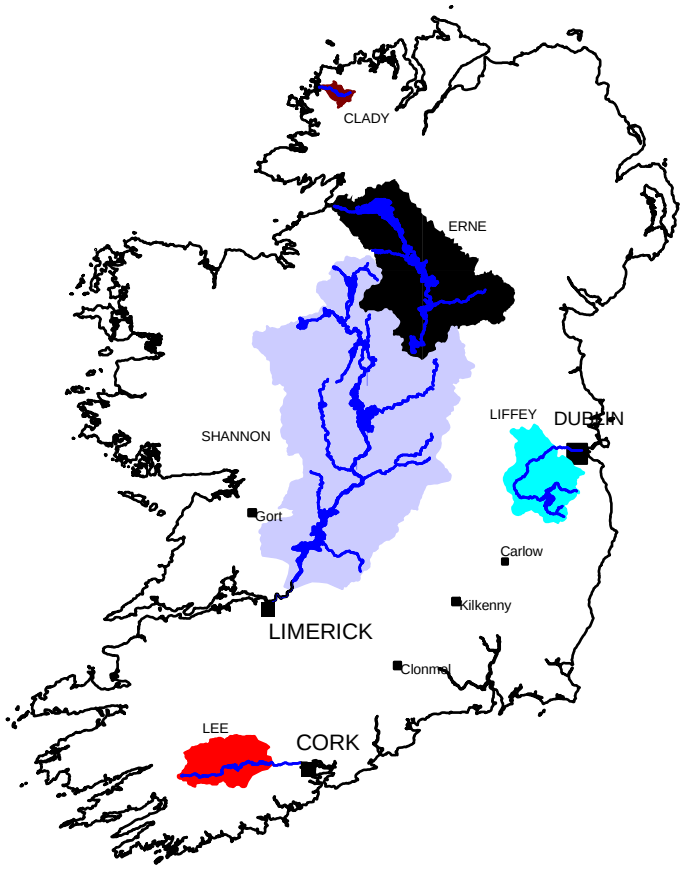

Figure 1-1: Location of catchments

Dams and reservoirs play a significant role in Ireland in flood risk management through the provision of storage and controlled discharge of flood inflows. Almost all of them were constructed more than fifty years ago. Although they have more than recovered their original investment, there are significant costs involved in operation and maintenance for flood control.

The objective of this paper is to illustrate the major benefits and the inherent risks of reservoir storage.

The ESB controls five catchments in Ireland namely, the Shannon (10,443km^2), Erne (4350km^2), Liffey (843km^2), Lee (793km^2) and Clady (80 km^2). The catchment locations are shown in Figure 1-1. Within these catchments, the ESB is the owner and operator of thirteen dam structures, most with reservoirs, which are associated with nine hydro-electric generating stations

These dams and reservoirs are multipurpose:

- They reduce significantly flooding impacts downstream and in the cities,
- They provide a major source of water supply to the cities of Dublin, Cork and Limerick,
- They provide a renewable source of electricity, and
- They are important for recreation and amenity.

2 LIFFEY

2.1 Liffey Reservoirs

The River Liffey, which rises at about 760 mOD in the Wicklow Mountains, is approximately 120km long from source to sea, draining an area of over 1,300km^2. Reservoir development on the river took place between 1937 and 1949, resulting in the commissioning of three dams namely Pollaphuca, Golden Falls and Leixlip – see Figure 2-1.

Figure 2-1: Liffey catchment (shaded) showing locations of ESB dams

The middle and lower reaches of the Liffey have in the past been subject to chronic flooding. The construction of the three Liffey Dams, particularly Pollaphuca with its large associated reservoir, has significantly reduced major flooding on the river.

Pollaphuca dam in the upper catchment is served by a catchment area of 308km² consisting mainly of a blanket bog overlying granite and having an average annual rainfall of 1,390mm. Pollaphuca Reservoir (Blessington Lake) is situated approximately 185m above sea level and has a surface area of 20km². The large storage available, at approximately 50% of the average annual inflow, is such that it has not been necessary, to date, to use the spillway gates.

Pollaphuca dam is a mass concrete gravity type dam. It has a total length of 79m with a maximum height of 32m. Dublin Corporation's main treatment works is nearby at Ballymore Eustace.

Golden Falls dam is situated about 2km downstream of Pollaphuca and acts as a regulating reservoir for discharges from Pollaphuca. It allows the generating turbines at Pollaphuca to run for four hours, filling Golden Falls. Then the volume of water is released downstream at a lower discharge rate over a 24 hour period. The dam is a mass concrete gravity type dam and has a total length of 100m and a maximum height of 15m.

After passing through Golden Falls, the Liffey flows approximately 56km through Co. Kildare to a relatively small reservoir at Leixlip, which is 20km from Dublin City. There are a number of small towns and villages located on its course, including Ballymore Eustace, Kilcullen, Newbridge, Straffan and Celbridge, all of which have the potential to be affected by extreme floods on the Liffey.

1.1 Flood Management

Water resources in the three reservoirs are managed remotely through operation of the generating stations and dam spillway gates.

In the Liffey catchment, Pollaphuca Reservoir is the principal means of flood control through the storage and controlled discharge of upper catchment inflow. The operating regulations stipulate that the water level in Pollaphuca reservoir be maintained between a maximum and minimum normal operating level. Should a storm occur in the catchment and increase the inflow to the reservoir and thereby cause levels to rise, the regulations provide a regime to store this inflow.

When levels continue to rise to pre-determined trigger levels, controlled discharges are implemented through either hydro generation or dam spillway operation. Pollaphuca reservoir has a substantial flood storage capacity which approximates to 50% of the average annual inflow. In its 60 year history, the dam spillway at Pollaphuca has yet to be used; it has been possible to discharge all floods via the generating station.

1.2 Historical Floods

The Liffey reservoirs have a major role in the attenuation of floods in the Liffey catchment. The beneficial effects of Pollaphuca reservoir in alleviating downstream flooding is clearly shown in Figure 2- which presents data in relation to the Liffey flood of November 2000. This graph illustrates the relationship between catchment rainfall, reservoir water level, reservoir inflow and dam discharge.

This was a significant flood event which is estimated to have a return period in excess of 50 years in the upper catchment. Heavy rainfall on the 5^{th} and 6^{th} of November 2000 in the eastern half of the country generated a major inflow to Pollaphuca reservoir from the upper Liffey catchment. As a result, the reservoir level reached its highest value in over 50 years.

Figure 2-2 indicates that this flood was stored in Pollaphuca until the peak of the storm was passed and then discharged in a controlled manner via the generating station. At its peak, the hourly inflow was estimated at over 420m³/s. This compares with the maximum discharge from Pollaphuca of 73m³/s.

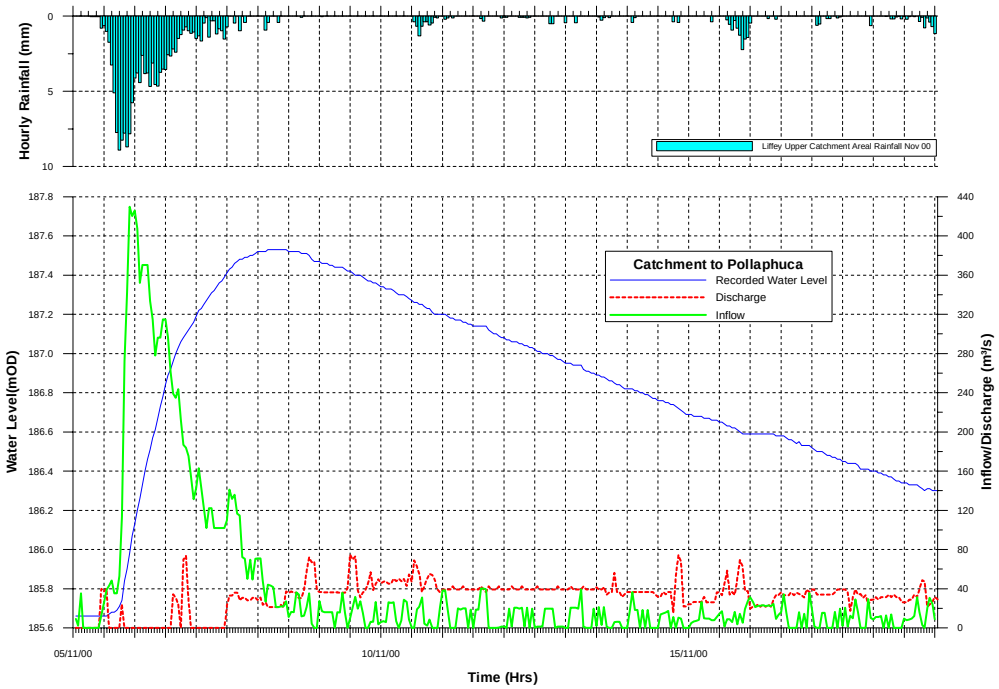

Figure 2-2: Management of November 2000 flood at Pollaphuca

Despite its relatively small size, further flood attenuation is achieved at Golden Falls reservoir, details of which are presented in Figure 2-3. The maximum inflow to the reservoir was 73m³/s which compares with the maximum discharge of just over 50m³/s. This attenuation was achieved by means of reservoir storage and discharge via the hydro station and spillway.

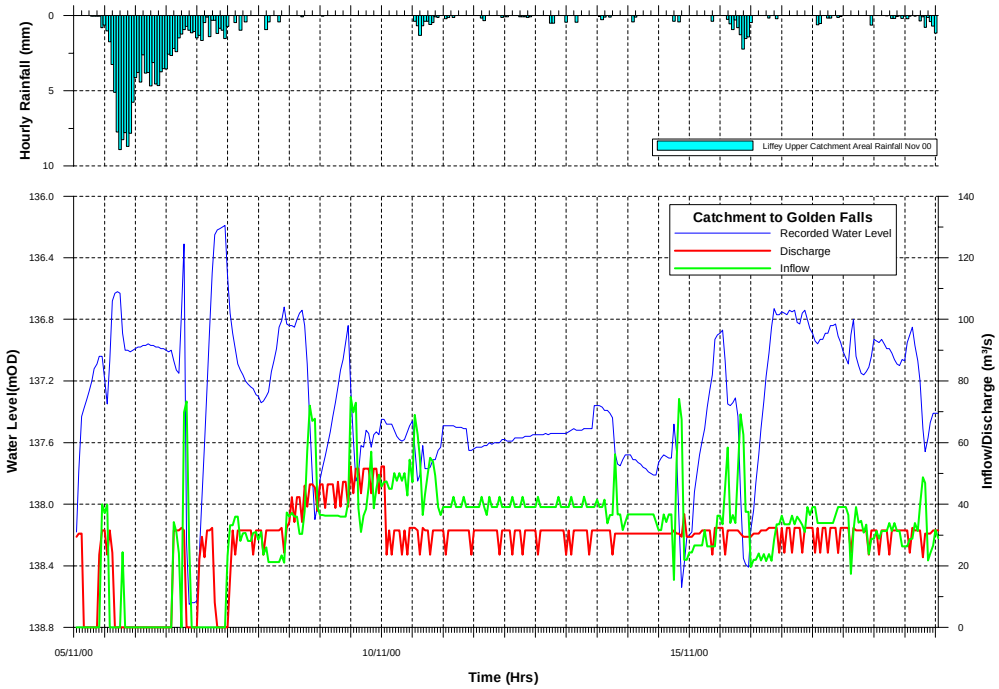

Figure 2-3: Management of November 2000 flood at Golden Falls

The Liffey Reservoirs have significantly reduced the frequency and extent of flooding along the Liffey as far as Dublin and this fact was highlighted in August 1986 when Hurricane Charlie caused extensive flooding on neighbouring catchments.

A hydrological model of the Liffey catchment was used to simulate what would have occurred in August 1986 if the reservoirs had not been constructed. The rainfall on the upper catchment was considerably more severe than that on the intermediate catchment. This model estimated that a flow approximately twice that which occurred in December 1954, the largest flood on record, would have occurred at Leixlip under these circumstances and there would have been extensive flooding of the Dublin suburbs. Extensive flooding occurred in 1954 in Lucan and Leixlip.

Figure 2-4 compares the recorded flow hydrograph at Leixlip with a simulation of the hydrograph which would have occurred if there were no reservoirs on the Liffey.

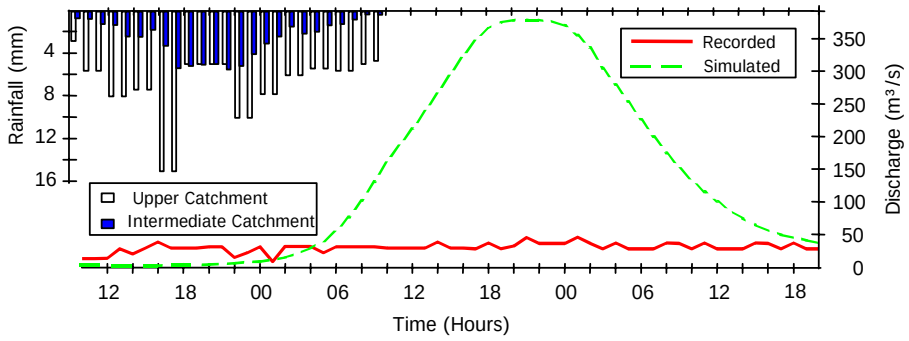

Figure 2-4: August 1986 Flow Hydrograph at Leixlip (Recorded v Simulated)

An analysis of the November 2000 Liffey flood was undertaken to estimate the impact of the Liffey dams on the magnitude of the flooding. The results of this analysis are contained in Table 2.1.

Location	Estimated Peak Liffey Flow (m³/s)	
	With dams	Without dams
Ballymore Eustace	55	425
Upstream of Leixlip	100	350
Downstream of Leixlip – incl. Rye Water	170	400

Table 2.1 : Estimated impact of Liffey dams on November 2000 flood

The analysis indicates that without the dams, it is likely that severe flooding would have occurred throughout the Liffey valley downstream to Dublin and that peak levels would have exceeded those which occurred in December 1954.

2. LEE

2.1 Lee Reservoirs

The River Lee rises near the border of Cork and Kerry in the steep mountains which encircle Gougane Barra lake. It flows almost due east along a narrow valley for about 65km to Cork City, draining a total area of over 1,100 km². See Figure 2-1.

Reservoir development was carried out on the Lee between 1953 and 1957. Two dams were constructed, at Carrigadrohid and at Inniscarra. Inniscarra dam is situated approximately 13km west of Cork City with Carrigadrohid Dam a further 14km upstream.

Carrigadrohid Dam is a concrete gravity dam 21.3m high, impounding a reservoir of 9km². The catchment upstream of the dam has an area of 616km² and is generally steep.

Inniscarra dam is a concrete buttress dam 44m high, with a reservoir approximately 5km² in area. The catchment upstream of Inniscarra and downstream of Carrigadrohid has an area of approximately 177km².

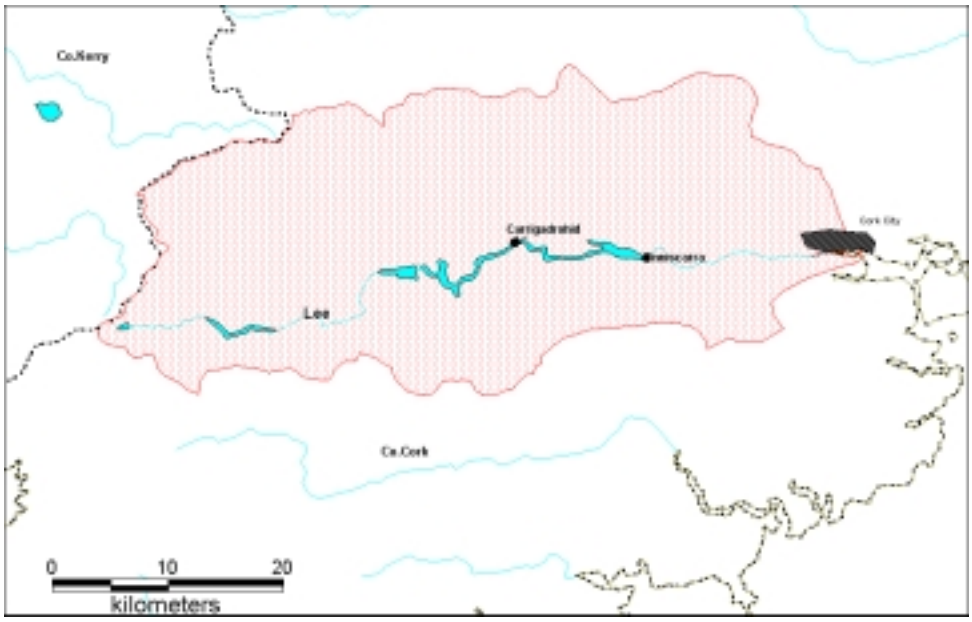

Figure 2-1: Lee catchment (shaded) showing locations of ESB dams

2.2 Flood Management

Inflow from the Upper Lee catchment is controlled at Carrigadrohid through storage in the reservoir and controlled discharge via Carrigadrohid Generating Station, three deep sluices and a spillway weir. Inniscarra reservoir provides additional flood storage potential and controlled discharge via Inniscarra Generating Station and three overflow spillway gates and thus regulates discharge downstream towards Cork City.

Rainfall data is transmitted to the control room from the upper catchment. Operations at both reservoirs are co-ordinated to optimise water management. They are also co-ordinated with forecast high tide levels in the city.

Downstream of Inniscarra, additional input to the Lee comes from the Bride, Shournagh and Curraheen catchments which comprise over 30% of the overall Lee catchment area.

2.3 Historical Floods

An indication of the flood attenuation offered by the Lee dams is given in Figure 3-2 using the example of the February 1997 flood. This figure illustrates the relationship between the overall catchment inflow to Inniscarra and the dam discharge. The overall catchment inflow incorporates Carrigadrohid discharge and natural inflow in the intermediate catchment and is broadly representative of the discharge which might have occurred without the presence of the

dams. The maximum inflow is estimated at 320m³/s which compares with the measured discharge of 230m³/s.

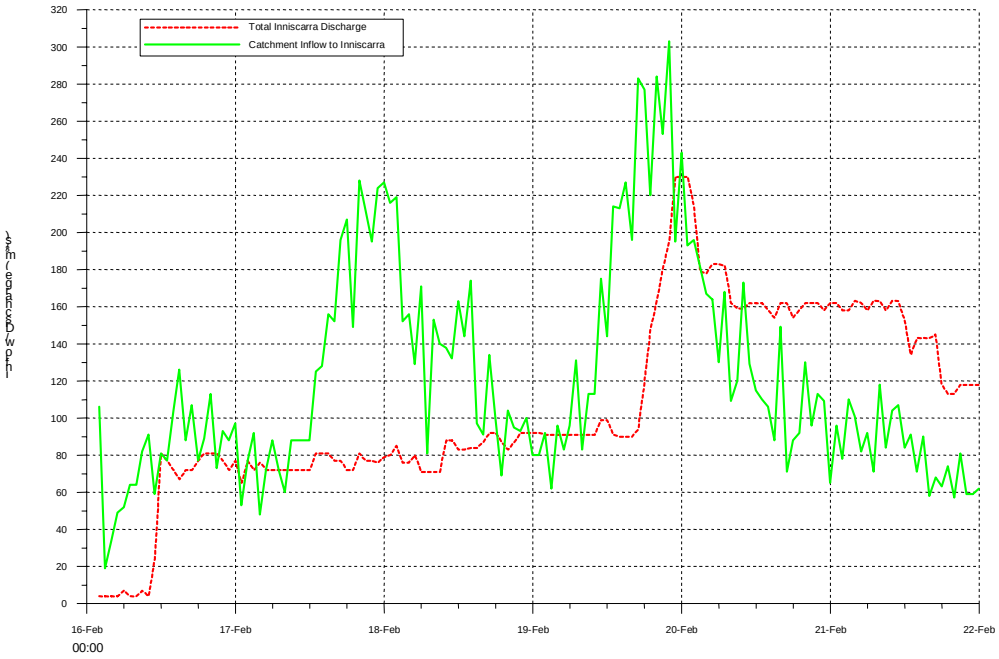

Figure 2-2: Management of February 1997 River Lee flood at Inniscarra

The storm on the River Lee catchment between the 5th and 6th of August 1986 generated significant discharges from Inniscarra dam reaching a peak of 331m³/s. The maximum inflow to Inniscarra for this storm was in excess of 500m³/s.

A study was undertaken by the ESB following this flood to provide comparisons of estimated flood levels in the Lee with and without the dams. The study indicated that flood levels would have been up to 0.8m higher in the Lee from Inniscarra to Cork City without the dams.

The Lee dams have reduced significantly the extent and frequency of flooding along the Lee valley into Cork City but because of the relatively small size of the Lee reservoirs, the amount of flood alleviation reduces for the more extreme flood events. Consequently a false sense of security may occur.

3. CLADY

The Clady System in north-west Donegal provides relatively small storage. The river drains a small mountainous catchment to the sea at Bunbeg. Two small lakes, Lough Dunlewy and Lough Nacung occupy the valley floor and drain the surrounding mountains, including Mount Errigal. See Figure 3-1.

The head of approximately 60m between Lough Nacung and the sea was developed by diverting a major portion of the Clady flow through a 2.7km canal and a 0.5km penstock to the Clady Generating Station on the edge of the estuary of the adjoining valley.

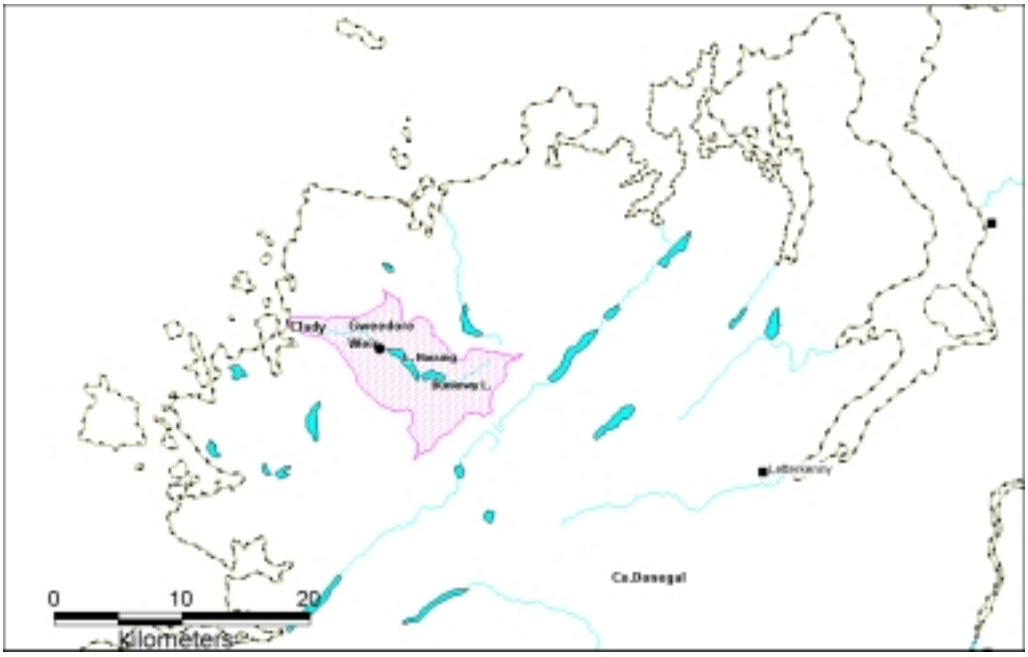

Figure 3-1: Clady catchment (shaded) showing location of Gweedore Weir

3.1 Flood Management

The development provides a mechanism for the management of floods on the catchment. Additional storage was provided in Dunlewy Lough and Lough Nacung. Flood discharges are automatically controlled by means of a 90m fixed weir at Gweedore.

The attenuation provided by the works is illustrated in Figure 4-2 which gives details of the August 1998 flood on the Clady. Peak inflow to Gweedore Weir is estimated at approximately 50m³/s. The maximum total channel discharge for this flood was estimated at just over 40m³/s. A flood wave passing through Lough Nacung and Lough Dunlewy is reduced in magnitude and lengthened in time as a result of the storage provided by the two lakes and the controlled discharge provided by the weir.

4. SMALL IMPOUNDMENTS

Numerous small to medium artificial lakes and reservoirs were constructed in the 18th and 19th century for the purpose of water supply and amenity. Although their original purpose is often long forgotten, they continue to attenuate flood flows and this benefit is not always recognised. Embankment dams control the impoundments, some up to six metres in height and the structure may receive little or no maintenance. Many are in private ownership on former estate lands while some are located in higher ground.

ESB International has assessed such impoundments in recent years and in some instances, recommendations were made for a safe breach of the dam and operation at reduced water levels.

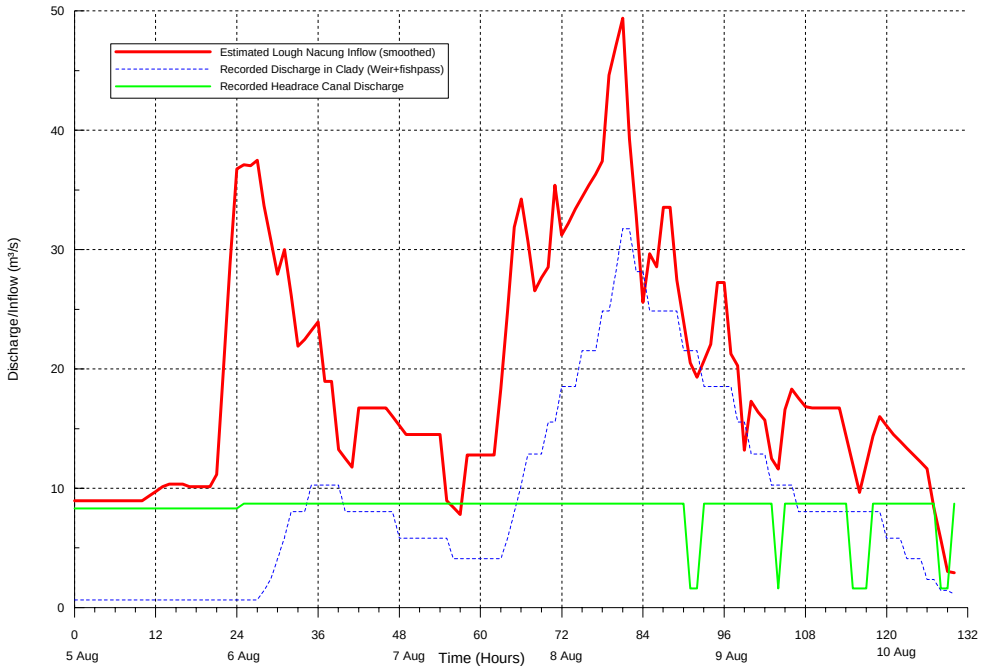

Figure 4-2: Management of August 1998 River Clady flood at Gweedore

The Brittas Ponds on the upper reach of the Camac River in Dublin is a case in point. The Camac rises in the Dublin Mountains and joins the Liffey at Heuston Station. The ponds were originally constructed to provide water for industrial use in the City. Flooding on the Camac has been an issue for South Dublin County Council in the past ten years, as the city has expanded rapidly. In the past, the headwater flows were heavily attenuated by the Brittas Ponds and the flood protection that they provided has been partly removed with the reduction in flood storage capacity.

Flood protection works have been completed downstream and further flood storage is being provided at Corkagh Park, located midway along the river. Here attenuation ponds will cover an area of 3.5 ha and have a maximum depth of 1.2m, operated as an urban wetland.

Moving to an even smaller scale, flood storage within new developments forms the final part of the spectrum. This solution counters the tendency for increased runoff from impervious areas. The design standards that are now required and use of oversized pipes and retention areas reduce runoff substantially, up to a defined frequency. Controlled release of floods up to the 20 year risk was applied in the past but this is often increased to the 50 year risk.

5. CONCLUSIONS

Artificial impoundments created by dams and retention storage have a major role to play in flood risk management in Ireland. Through the controlled discharge of flood inflows, they provide a significant degree of flood protection to downstream settlements and land. The impact of the flood events of November 2000 and August 1986 along the River Liffey and River Lee were greatly reduced through the intervention of the Liffey and Lee dams respectively. The populations downstream of the dams now take the increased security against flooding as normal.

It must be noted that the ability of an impoundment to accommodate flood storage is limited by the physical dimensions of the impoundment. Therefore, the degree of attenuation of floods reduces with more extreme flood events and this has the potential to lead to a false sense of security.

Active management of flood risk through use of large dams and reservoirs is an ongoing process. Optimisation of flood management is reviewed periodically. The ESB undertakes detailed analyes of all major floods and incorporates any appropriate findings into operating regulations. Computerised flood management and reservoir routing software packages have been developed to assist reservoir operations.

Dams and impoundments are permanent structures and are now part of the landscape. However, they are artificial structures impounding volumes of water, either large or small, and as such must be subject to constant monitoring and maintenance.