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SUBJECT
Prince Llewelyn Reservoir

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TITLE
Prince Llewelyn Reservoir Flood Consequences Assessment

CLIENT
Natural Resources Wales - Jo Parkinson / Paul Risdon

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1. Introduction

Arcadis has been commissioned by Natural Resources Wales (NRW) to produce a Flood Consequences Assessment (FCA) to support the design of a new lowered spillway to facilitate the discontinuance of the Prince Llewelyn Reservoir.

NRW owns Prince Llewelyn Reservoir which is located in Snowdonia National Park, North Wales. This small raised reservoir has a capacity of less than 10,000m^3 and is therefore not subject to statutory safety requirements under the Reservoirs Act 1975 (as amended by the Flood and Water Management Act 2010). Nevertheless, NRW considers the reservoir to be a high priority site and is consequently treating it in the spirit of the Act (NRW, 2016). As a result, NRW commissioned a flood study (undertaken in accordance with the fourth edition of Floods and Reservoir Safety (ICE, 2015)) and reservoir inundation mapping (undertaken in accordance with Environment Agency's (EA, 2016) Reservoir Flood Mapping (RFM) Specification Version 1.0.1) for the reservoir.

The flood study (Arcadis, 2018a) concluded that the reservoir does not meet the required safety standards for a Category A/B dam (the findings of the reservoir inundation mapping (Arcadis, 2018b) appear to support the categorisation of the reservoir as category B). In particular, there is zero freeboard and insufficient spillway capacity during both the Design Flood and the Safety Check Flood.

Following the production of the flood study, a further study (Arcadis, 2019a) was carried out to support the development of a new lowered spillway design (the Scheme) to meet the recommended safety standards. In the subsequent review of the flood study (Arcadis, 2019a), it was agreed in consultations between NRW and the Qualified Civil Engineer (QCE) that, since Prince Llewelyn is not a Statutory Reservoir and the options investigated would further reduce the retained volume, the design flood could be changed from a 1-in-10,000 year (0.01% Annual Exceedance Probability (AEP)) to a 1-in-1,000 year (0.1% AEP) flood. Furthermore, it was also agreed that there would be no requirement to meet the safety check flood standard. On construction and maintenance grounds (e.g. reduced blockage risk), there was also a change in Arcadis' Design Engineers and NRW's preferred Scheme.

The FCA (Arcadis, 2019b), which was originally produced to support the Scheme, has therefore been updated to demonstrate that the latest preferred Scheme would not result in an increase in downstream fluvial flood risk.

2. Site Description

2.1 Site Location and Description

Prince Llewelyn Reservoir is located on the north side of the Lledr valley, between the villages of Dolwyddelan and Betws-y-Coed (NGR SH 74232 53049), as shown in Figure 2-1. It is a rectangular-shaped reservoir covering an area of approximately 2,600 m^2 and has a retained volume of 5,477 m^3. The reservoir is surrounded by coniferous stands and lies at the edge of a plantation forest. A handful of properties lie within 300 m of the toe of the dam, including a row of six terraced houses known as Prince Llewelyn Terrace.

The A470, the main trunk road between Cardiff and Llandudno, also passes within 260 m of the dam.

In view of its surroundings, the QCE initially recommended that Prince Llewelyn reservoir be treated as a Category A/B dam (NRW, 2016). In other words, a dam breach “could endanger lives in a community” (ICE, 2015). However, following the review of the flood study (Arcadis, 2019a), it was agreed in consultations between NRW and the QCE that, since Prince Llewelyn is not a Statutory Reservoir and the options being considered would further reduce the retained volume, the reservoir did not need to be treated as a Category A/B dam, and as a result there was scope to modify the design flood requirements and remove the requirement to satisfy the safety check flood standards.

The reservoir used to be fed partly by a leat which can be traced on old Ordnance Survey maps and was found to be in a ruined state when inspected in 2011. For the purposes of the flood study, it was assumed that Prince Llewelyn reservoir can no longer receive flows from outside of its natural topographic catchment.

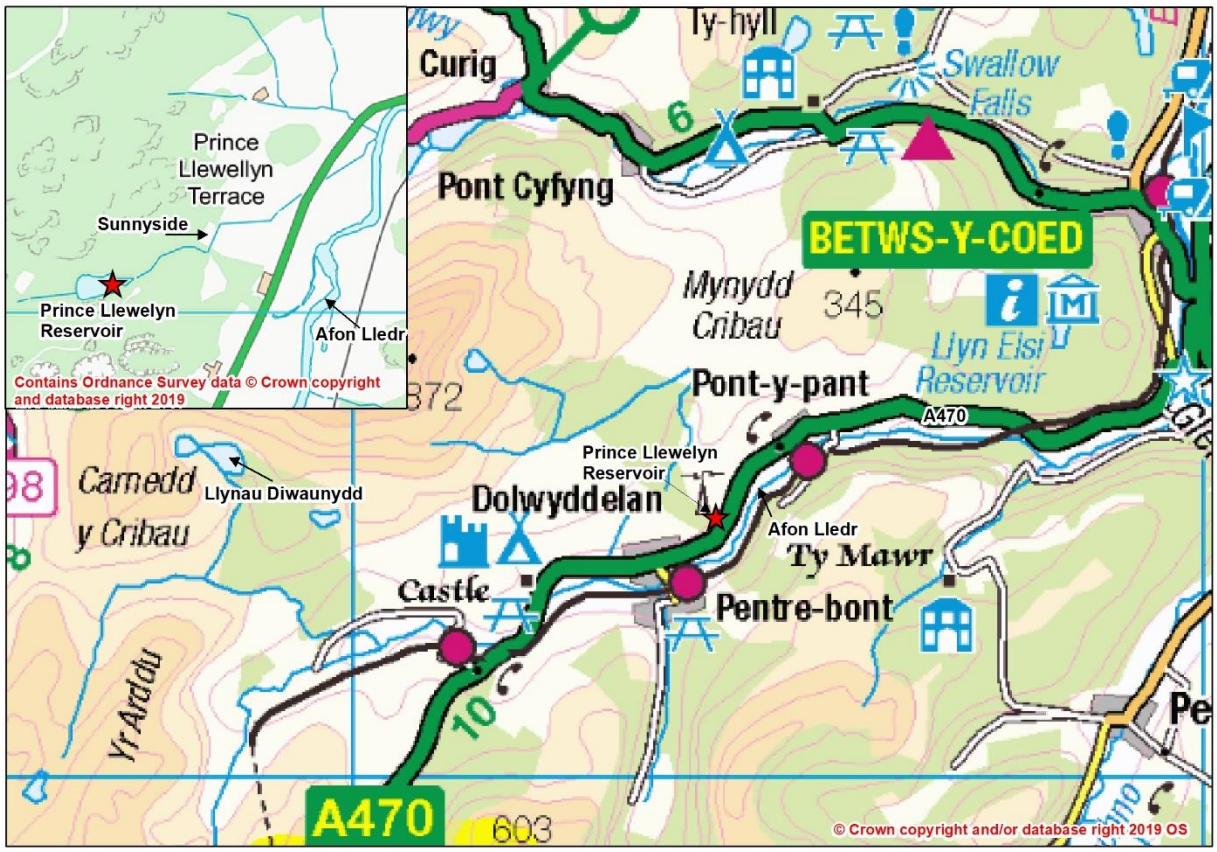

Figure 2-1: Prince Llewelyn Reservoir Location

2.2 Topography & Catchment Description

The reservoir is located at an elevation of around 196 m AOD. Its outlet is at 191.8 m AOD and it has an average embankment crest level of 196.43 m AOD.

Prince Llewelyn reservoir has a very small natural catchment, with an area of approximately 0.046 km^2. It receives an average annual rainfall of 2,010 mm (CEH, 2018). The altitude of the catchment ranges from 194 to 238 m AOD, while the mean drainage path slope (DPSBAR) is 179 m/km (based on LiDAR data). Further detail of the hydrology can be found in the further Flood Study report (Arcadis, 2020).

The watercourse (classified as an ordinary watercourse) from the reservoir discharges into the Afon Lledr, an NRW designated main river, which flows parallel to the A470 before joining the River Conwy near Betws-y-Coed.

2.3 Flood History and Defences

No detailed flood risk or historical flood mapping associated with the reservoir and the downstream watercourse is available[1]. There are no formal flood defences along the watercourse between the reservoir and the confluence with the Afon Lledr.

2.4 Proposed Scheme

The Flood Study that has been undertaken (Arcadis, 2020), confirmed that the existing reservoir spillway (currently 2 m wide) does not pass the Design and Safety Check Flood flows safely.

To enable the reservoir to meet the required design and safety check flood standards two options were initially developed. These options were developed using the findings of the NRW option selection workshop (January 2019) and in consultation with NRW and Arcadis' Design Engineers.

In the subsequent review of the flood study (Arcadis, 2019a), it was agreed that the design flood could be changed from a 1-in-10,000 to a 1-in-1,000 year flood. Furthermore, on construction and maintenance grounds, there was also a change in Arcadis' Design Engineers and NRW's preferred Scheme.

This new preferred Scheme, 'Option 3', involves lowering the spillway to an elevation of 193.3 m AOD, which would reduce the retained volume to 599 m^3 (without silt). The lowered spillway for this alternative option has been modelled as a stepped spillway with the spillway crest 2 m wide and 0.6 m deep, stepping up to the existing embankment average elevation (196.43 m AOD).

The following sections of this report demonstrate that the Scheme would not result in an increase in downstream fluvial flood risk.

3. TAN15 Development and Flood Risk

Technical Advice Note (TAN) 15 provides guidance to local planning authorities in determining planning applications with regards to flood risk and provides an interpretation of how this guidance applies specifically to a site. It 'provides a framework within which risks arising from both river and coastal flooding from additional run-off from development in any location can be assessed'. This 'precautionary framework should be used for both forward planning and development control purposes'. Its operation is governed by:

A Development Advice Map (DAM) containing three zones (A, B and C with subdivisions C1 and C2) which should be used to trigger the appropriate planning tests in relation to Sections 6 and 7 and Appendix 1 (TAN15, para 3.2).

Definitions of vulnerable development and advice on permissible uses in relation to the location of development and the consequences of flooding (TAN15, para 3.2).

The approach is therefore staged:

1. Categorisation of site within TAN15 Flood Zones.
2. Application of TAN15 precautionary framework and determination of whether the proposed Development is 'justified' in that zone (TAN 15 Section 6 test).
3. Assessment of flooding consequences (TAN15 Section 7 test and Appendix 1) and production of a Flood Consequence Assessment report.

[1] https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=1

The DAM[2] shows Prince Llewelyn reservoir to be located within Zone A. Flood Zone A is considered to be at little or no risk of fluvial or tidal/coastal flooding. Under the precautionary framework it indicates that the justification test is not applicable and there is no need to consider flood risk further. However, given the nature of the proposed Scheme, an FCA was commissioned by NRW as works to the reservoir spillway could affect flood risk downstream.

It is considered that the Scheme meets the justification test as it is located within Zone A and is classified as essential infrastructure (works undertaken in the interest of safety) and water compatible.

4. Flood Consequences Assessment

Apart from fluvial/surface water flowing into the reservoir, the Scheme is not at risk of flooding.

Although not subject to statutory safety requirements, the reservoir in its current form does not meet the required safety standards for a Category A/B dam.

Owing to the reduction in the retained volume (from 5,477 m^3 to 599 m^3) with the Scheme in place, the QCE agreed that there would be no requirement to treat the reservoir as a Category A/B dam and, therefore, the Scheme has been designed to meet the 1-in-1,000 year design flood standard. This considers the design fluvial/surface water flood flows into the reservoir.

With the construction of the stepped spillway and the reduction in retained volume, the Scheme will reduce the downstream risk of extreme flooding by reducing the likelihood and consequences of a dam breach failure. The property damages (consequences) associated with a failure of the current dam (on a wet day with river flooding) are estimated to be in the order of £30k (Arcadis, 2018b); therefore, although the damages associated with a failure of the Scheme have not been estimated, they can be expected to be significantly reduced with the Scheme in place for the events discussed.

By changing the existing spillway (which is a key control on the flow attenuation of the reservoir), the Scheme has the potential to increase downstream fluvial flood risk in medium frequency flood events (e.g. 1-in-10 year (10% AEP)) to 1-in-100 year (1% AEP)). Although in these events the percentage change in outflow ranges between +5.9% and +7.3%, in reality the actual change in flow is relatively small (between 5 l s^{-1} and 8 l s^{-1}). This level of increase is considered to result in an insignificant change to downstream flood risk.

Further information on the existing flood attenuation (e.g. volume of temporary storage) and modelling undertaken to configure the spillway geometry is provided in the Flood Study (Arcadis, 2020).

Downstream of the dam there are several potential vulnerable receptors including properties (Prince Llewelyn Terrace) and the A470. In the higher frequency flood events (up to and including the 1-in-1000 year event), there will be a relatively small increase in downstream flows (maximum 13 l s^{-1}), therefore the Scheme would represent an insignificant change in downstream flood risk to these receptors.

5. Conclusions

Prince Llewelyn Reservoir is not subject to statutory safety requirements under the Reservoirs Act 1975 (as amended by the Flood and Water Management Act 2010). Nevertheless, NRW considers the reservoir to be a high priority site and is consequently treating it in the spirit of the Act (NRW, 2016).

Although not subject to statutory safety requirements, the reservoir in its current form does not meet the required safety standards for a Category A/B dam.

Two initial lowered spillway design options were developed to meet the recommended safety standards.

[2] https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=1

Owing to the associated reduction in the retained volumes that these two options provided, the QCE agreed that there would be no requirement to treat the reservoir as a Category A/B dam and, therefore, the Scheme could be designed to meet the 1-in-1,000 year design flood standard. As a result, a third option, 'Option 3', was developed, which also considered design changes associated with construction and maintenance (e.g. reduced blockage risk).

Although with the Scheme in place (Option 3), the percentage change in outflow will slightly increase (maximum +7.3%), in reality the actual change in downstream flow will be relatively small (between 5 l s^{-1} and 8 l s^{-1}). This level of increase is considered to result in an insignificant change to downstream flood risk. Furthermore, the Scheme will reduce the downstream risk of extreme flooding by reducing the likelihood and consequences of a breach failure.

6. References

Arcadis. (2018a). *UA008946-ARC-XX-XX-RP-CW-0006-03-Prince Llewelyn.*

Arcadis. (2018b). *UA008946-ARC-XX-XX-RP-CW-0007-01-RFM Prince Llewelyn.*

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CEH. (2018). *FEH Web Service*. Retrieved from Flood Estimation Handbook: https://fehweb.ceh.ac.uk/Home

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